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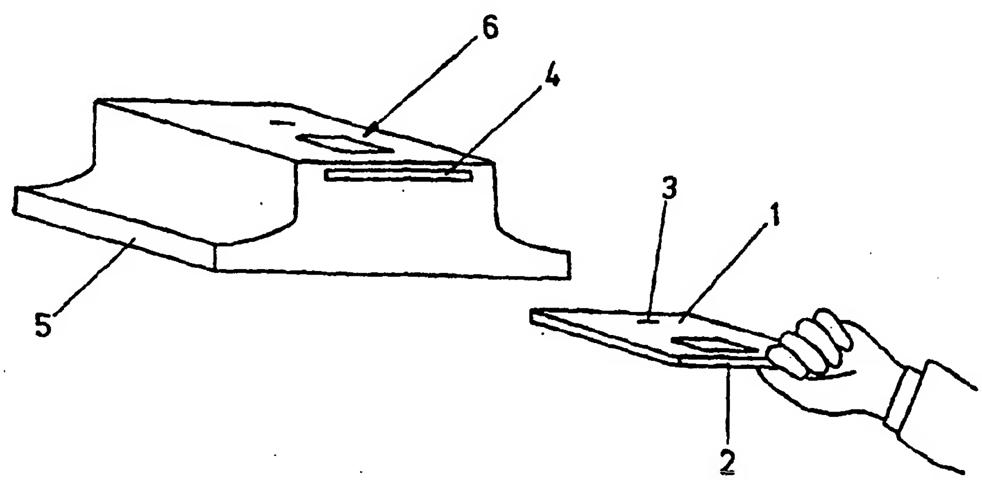

(57) Abstract

A system used in fingerprint identification for determining distinguishing features of a fingerprint pattern and comparing these to an allowable fingerprint pattern, includes a card (2) having a sensor (1) for producing a sequence of fingerprints pattern data representative of a finger pressed thereon and processing means for producing processed data indicative of the relative positions of the epidermal ridge minutiae and the epidermal ridge sweat pores of the fingerprint pattern. The processed data is stored and used for identify verification.

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FINGERPRINT SENSOR

This invention relates to fingerprint sensors.

The invention provides a verification method for use with a fingerprint sensor, the fingerprint sensor comprising an array of individually actuable sensing cells, the sensing cells each being actuated by the presence or absence of contact of the respective cell by the epidermal ridges of the fingerprint pattern of a finger positioned on the sensor, each actuated sensing cell contributing to a sensor output signal indicative of the relative positions of the actuated sensing cells, the verification method comprising the steps of processing the sensor output signal to produce a processed signal indicative of the relative positions of distinguishing features of the sensed fingerprint pattern, comparing the processed signal with a set of allowable signals stored in a memory means, and producing an authorisation signal when the processed signal matches an allowable signal.

The invention also provides a sensor comprising an array of individually actuable sensing cells and a resiliently deformable membrane defining a sealed space above the individually actuable cells, wherein the sealed space is entirely filled with a pre-selected volume of a substantially incompressible fluid and the individually actuable cells are actuated by the deformation of the membrane to produce output signals distinguishing those

cells which have been actuated from those which have not been so actuated.

The invention also provides a fingerprint sensor comprising an array of individually actuable sensing cells, wherein the cells each include a vibratable sensing element responsive to the presence or absence of contact of the cell by a fingerprint epidermal ridge and driving means for vibrating the sensing element, and the sensor further comprises detection means responsive to the extent of vibration of each of the sensing elements to produce output signals distinguishing those cells contacted by an epidermal ridge from those not so contacted.

Embodiments of the present invention will now be described, by way of example, and with reference to the accompanying drawings, in which:

Figure 1 illustrates a credit or bank card verification system incorporating the present invention;

Figures 2a and 2b illustrate side and top views respectively of an alternative credit, identity or bank card verification system incorporating the present invention;

Figure 3 is a view of the top surface of the card of Figure 1 or Figure 2;

Figure 4 is a view of the card with a portion of the card

surface removed;

Figure 5 is a section of part of the card showing electronic components supported on the card, with the card unflexed;

Figure 6 is a view similar to Figure 5, with the card flexed;

Figure 7 is a plan view of a sensor mounted on the card of Figure 3;

Figure 8 is a plan view of an alternative sensor construction;

Figure 9 is a perspective view of the sensor of Figure 8;

Figures 10a and 10b are views in partial section along line VII-VII of Figure 7 with the membrane undeformed and deformed respectively;

Figures 11a to 11g are plan views of some of the layers an alternative sensing cell construction formed by a number of different layers;

Figures 12a to 12c are three dimensional views of some of the layers of the sensor of Figures 11a to 11g;

Figures 13 and 13b are a schematic illustration of the operation of the sensing cell of Figures 11 and 12;

Figure 14 is a cross-sectional view of an alternative construction of the upper layers of a sensing cell having a vibratable sensing element;

Figure 15 is an enlarged view of a detail of Figure 14;

Figures 16a and 16b are a schematic illustration of the operation of the sensing cell of Figure 14;

Figure 17 is a cross-sectional view of a further alternative sensor construction;

Figures 18a to 18c are illustrations of three further alternative sensing elements for the sensor having a vibratable sensing element;

Figure 18 is an illustration of the vibratable sensing element;

Figure 20 is a schematic illustration a detail of the fingerprint sensor;

Figure 21 illustrates a window in the card receiver of Figure 1;

Figure 22 illustrates the window shown in Figure 21 with a finger positioned thereon;

Figure 23 illustrates a portion of a thermocouple array of Figures 21 and 22, on an enlarged scale;

Figure 24 is a section through one thermocouple on a further enlarged scale;

Figure 25 is a diagram illustrating flows of data between the card and card receiver;

Figure 26 is a flow chart illustrating a verification method;

Figure 27 is a flow chart illustrating a method of characterising the dimensions of a finger;

Figure 28 is a flow chart illustrating a method of determining the location of epidermal ridge sweat pores in a fingerprint pattern;

Figure 29 illustrates a method of determining the location of fingertip sweat pores;

Figure 30 is a graphical representation of the input to and output from the sweat pore location method;

Figure 31 is a flow chart illustrating a method of determining the location of ridge minutiae;

Figure 32 is a flow chart illustrating an alternative method of determining the location of ridge minutiae;

Figure 33 illustrates a method of determining the location of fingerprint minutiae (fingerprint minutiae are those

points in the pattern where epidermal ridges either end or form bifurcations);

Figures 34a to 34b illustrate a portion of the sensor activated by fingerprint ridge endings or bifurcations respectively;

Figure 35 is a graphical representation of the input to and output from the minutiae location method; and

Figure 36 is an illustration of a system of classifying features of a fingerprint pattern;

Figure 37 is a flowchart illustrating a method of classifying a sensed fingerprint pattern; and

Figure 38 is a block diagram illustrating the flow of data in the credit or bank card verification system.

Fingerprint sensors for determining a fingerprint pattern will now be described, by way of example, with reference to Figures 1 to 24.

Referring to Figure 1, a credit card 1 with a sensor 2 and electrical contacts 3 is removably inserted in a slot 4 in a card receiver 5. The card receiver 5 has a window 6 through which a portion of a finger may be pressed on the sensor 2 of a card located in the receiver.

Figure 2 shows an alternative form of verification system.

A credit card having a magnetic strip is swiped through the swipe reader 30 and details of the proprietor or authorised user of the card read from the magnetic strip. The card receiver 31 has a built-in sensor 2 and a microprocessor 32. The microprocessor may be a Neural Instruction Set Processor.

A plastics carrier 7 has a thin layer 8 of nickel (approximately 0.05mm thick) electroformed onto its surface. The nickel layer is anodised and then coated with a thin uniform layer of polyimide.

The sensor 2 and its associated electric circuit, including sensor inputs (or drivers) 9, sensor outputs (or latches) 10, a card microprocessor 11 and electrical contacts 3 are mounted on the inert nickel supporting layer 8. The sensor circuit 2, 3, 9, 10, 11 and plastic carrier 7 are encapsulated within a plastic card envelope 12 to conform to ISO standards.

The high modulus of elasticity (Young's Modulus) of the nickel support 8 relative to the plastic card elements 7, 12 results in a card neutral axis of bending which lies within and through the nickel support 8. The sensor electronics 3, 9, 10, 11 are therefore close to the neutral axis at bending strain when the card is flexed.

With reference to Figures 4 and 7, the sensor 2 is driven by eight discrete input gate arrays 9 and its output connected to eight discrete output gate arrays 10. Each

gate array is approximately 1mm square and is connected to a portion of the sensor.

The gate arrays are arranged around the perimeter of the square sensor 2 in alternating groups of four input arrays 9 and four output arrays 10.

Figure 8 shows an alternative configuration where the sensor 2 is driven by sixteen input gate arrays 9 and its output connected to sixteen output gate arrays 10. The number of input and output gate arrays depends on the size of the sensor array, its density of sensing cells and the capacity of the gate arrays. The gate arrays 9, 10 of the sensor of Figure 8 are arranged in alternating groups of eight input gate arrays and eight output gate arrays.

The sensor 2 may be adapted to engage with a standard pin grid array package (see Figure 9). The sensor 2 is provided with pins 33 which form the electrical contacts for flow of power and data between the sensor and the circuitry connected to a package.

Each gate array is connected to the card electrical circuit using 0.13 mm square soft solder pillars (or pads) 13 (see Figure 5). The solder connections 13 are arranged near the centre of each gate array so that when the card 1 is flexed the solder pillars 13, having a low modulus of elasticity compared to the silicon gate arrays 9, 10, accommodate the curvature and absorb any strain.

The sensor 2 includes a square matrix 14, (12.55 mm x 12.55 mm) of pressure sensitive cells (approximately 100 μm square)mounted on an undeformable support.

Referring to Figures 7, 10a and 10b, the cells of a first type of sensor array (or matrix) construction are defined by the cross-over points of a number of electrical conductors arranged in rows and columns. This construction of the matrix 14 of pressure sensitive cells is described in detail in EP-A-459808.

The sensor matrix 14 and gate arrays 9,10 are deposited on the nickel layer in a series of steps suitable for a flow line production process. The gate arrays 9,10 are first deposited at pre-determined locations on the inert nickel support layer. The rows and columns of electrical conductor defining the sensor matrix are then deposited in separate operations and are deposited so as to directly connect with the output gate arrays and input gate arrays respectively.

A thin MYLAR (trade mark) membrane 16 (5 to 20 μm, preferably 5 to 10 mm thick) having an array of metallic contact bridges deposited on its lower surface is supported approximately 20 μm above the conductor rows and columns.

Current is supplied via the input gate arrays 9 to the matrix columns and a resistive connection between a row and a column occurs when a membrane contact bridge is

brought into contact with a cross-over point. The input and output currents in the columns and rows can be measured as described in EP-A-459808 to provide signals representative of the state of each cross-over point. These signals are latched into shift registers.

A circular elastic member 15 is located in a circular groove which extends around the sensor 2 and gate arrays 9, 10 (see Figure 7).

The membrane 16 is fixed to the elastic member 15 and is subjected to a residual tension. The membrane 16 and elastic member 15 define a sealed space 17 which is filled with a controlled volume of an incompressible silicone liquid 18.

When a finger is pressed against the Mylar membrane 16, the pre-selected volume of silicone liquid forces the membrane to conform to the shape of the fingerprint pattern. Those parts of the membrane 16 which conform to fingerprint ridges will be brought into contact with the sensor matrix. The membrane contact bridges will connect the matrix rows and columns at those positions within the matrix corresponding to fingerprint ridges and a matrix of electrical signals representing the fingerprint pattern is produced.

The volume of the silicone liquid is selected so as to ensure that when a finger tip is pressed down on the Mylar membrane 16, those portions of the membrane 16 in contact

with an epidermal ridge are brought into contact with the conductor rows and columns and those portions of the membrane 16 corresponding to epidermal valleys are deformed by the incompressible fluid so as to extend into the epidermal valleys.

The volume of the silicone liquid should therefore be selected so as to be equal or less than the volume of the valleys. If the liquid volume is greater than the volume of the valleys the membrane contact bridges will not be brought into contact with the cross over points. The volume of the silicone liquid should also be large enough to ensure that these portions of the membrane 16 corresponding to valleys are sufficiently deformed into the valleys so as to be clearly distinguished from those portions of the membrane 16 corresponding to ridges.

The silicone fluid 18 improves the conformability of the Mylar membrane 16 and hence the sensor's accuracy. The fluid also smoothens out the ridge contours and eliminates minute ridge variations.

Fingerprint ridges and valleys are each approximately 400 μm wide, and finger sweat pores are approximately 100 μm wide. The output produced by the matrix (the matrix consisting of 100 μm square cells) is therefore capable of resolving fingerprint ridges and those sweat pores located in a fingerprint ridge (see Figures 30 and 33).

The elastic member 15 deforms elastically (see Figures 10a and 10b) when the membrane 16 is distorted and no longer in its equilibrium position. The deformation of the elastic member 15 results in an increased membrane tension and therefore acts to restore the membrane 16 to its equilibrium position.

The elastic member 15 therefore reduces the likelihood of a fold occurring in the membrane 16 which may then be trapped by a finger and generate false or misleading data.

Referring to Figures 11 to 19, in an alternative type of sensor construction the cells 34 are defined by a matrix of vibratable piezo-electric sensing elements 35. The vibration of the sensing element 35 induces stresses therein and therefore generates an electric field. Contact of a vibrating sensing element 35 by an epidermal ridge of a fingerprint pattern will dampen the vibrations and thereby alter the electric field generated within the piezo-electric material by the stresses associated with its vibration.

A substantially non-deformable insulating substrate 36 (see Figure 11a) which may be of plastics, glass, silicon or other suitable insulant is masked and coated by, say, plating or vacuum deposition with a metal to form a number of parallel column electrodes 37 94μm wide and spaced 6μm apart (see Figures 11b and 12a). The spacing between the centre of adjacent columns 37 determines the width of the sensor cells. The cell density may be altered by changing

the width and/or separation of the column electrodes 37.

A first layer 38 of an insulant such as polyimide (see Figures 10c and 11b) is deposited on top of the column electrodes. First vias 39 through the first insulating layer 38 to each of the column electrodes 37.

A second deposition of metal (not shown in Figures 10 or 11) is carried out to provide parallel row electrodes (not shown in Figures 11 or 12) separated from the column electrodes by the first insulating layer and displaced from the first via in the first insulating layer. The row electrodes are orthogonal to the column electrodes and are spaced at 100μm intervals. This is essentially the same procedure as for the column electrode and is not shown in Figures 11 or 12.

A second insulating layer is then deposited on the row electrodes (not shown). First and second vias are provided therein to allow access through the insulating layer to the column and row electrodes respectively.

A thin film resistor 40 of Nichrome or a similar stable material of low temperature coefficient is deposited on the second insulating layer with one end connected through the first vias to the column electrode (see Figures 11d and 12c). The thin film resistor 40 may, in an alternative configuration, be deposited below the column electrodes and connected by appropriate vias. The thin film resistor is deposited in a meander configuration so

as to maximise its resistance whilst keeping it small enough to fit within the sensor cell. The resistance of the thin film resistor can be further increased by making successive layers of the resistor separated by insulant (see Figure 19).

A further insulating layer 46 is deposited on the Nichrome resistor. First 39 and second vias (not shown) are provided to allow access to the resistor (and hence to the column electrode) and row electrode respectively.

Two separate but interdigitated elements 35, 48 of a piezo-electric material such as polyvinylidene fluoride (PVDF) are then deposited on the further insulating layer 46 (see Figures 11f and 12e). One of the piezo-electric elements 48 (the driving element) has a first end connected through the first vias with the resistor and column electrode and its second end connected to earth (or ground) (see Figure 13a). The second piezo-electric element 35 (the serving element) has a first end converted through the second vias with the row electrode and its second end connected to earth (or ground) (see Figure 13b). The piezo-electric elements 35, 48 of each cell are separated from those of adjacent cells.

A layer of a metal 49 such as chromium is then deposited on the interdigitated piezo-electric elements 35, 48. The chromium layers on the first (i.e. driving) and second (i.e. sensing) elements of each cell are separated from those of adjacent cells. In an alternative construction,

the metal layers on the driving elements in each row may be connected so as to form a single continuous layer along the row.

The chromium layer 49 acts as a support for the PVDF and to filter any infra red by conducting heat applied to the sensor by the fingertip throughout the surface of the sensor. The chromium layer on the sensing element may also be used as a contact for an alternative construction of row electrode (bus) which can be directly connected to the chromium layer. The column electrodes 37 of the sensor are each connected to an alternating voltage supply which can apply a pulse 51 of alternating voltage to the first driving piezo-electric element (see Figure 13a). The pulse of alternating voltage causes the driving piezo-electric element 48 to vibrate (see Figure 13a). The voltage supply is a square wave pulse and its amplitude is within the range of TTL voltage. The column electrodes are essentially an input bus to the sensor array. The vibrating of the driving element causes the second, sensing element 35 to vibrate in sympathy. This vibration of the sensing element induces stresses therein and thereby produces an electric field in the sensing element which produces a voltage at the row electrodes 52 (see Figure 13b). These voltage outputs from the row electrodes of the sensor array form the output bus of the sensor array system and are monitored by a sensing circuit 53.

Contact of the sensing element 35 by an epidermal ridge of

a fingerprint pattern will dampen its vibrations and result in a change in the electric field produced in the sensing element by its piezo-electric properties. This results in different output signals between those cells actuated by contact with an epidermal ridge and those not so actuated.

The input and/or output circuits may be equipped with means for selecting a particular cell and determining its state.

These changes in output are monitored and the relative positions of actuated and non-actuated sensor cells determined.

The output may be represented by a matrix having positions corresponding to each of the cells of the sensor array and wherein actuated cells are indicated by a "1" (i.e. high) and non-actuated by a "0" (i.e. low).

Referring to Figure 14, an alternative configuration of the driving 54 and sensing 55 elements has them one above the other rather than interdigitated together in the same horizontal place. The sensing element 55 is supported above the driving element 54 by insulating spacers 60 defining a void 61.

Column and row electrodes separated from each other by insulating layers (not shown) are deposited on a substrate in a similar manner to that described above.

A further insulating layer is deposited on the row electrode. A third, scanning electrode 71 is then deposited on this further insulating layer before being itself then covered by a deposition of another insulating layer. This is not shown in Figure 14 or described in detail as it is well known in the art. The scanning electrode is connected to an addressing circuit 69 for addressing each cell or group of cells in turn in scanning array.

A thin film resistor 62 of, say, Nichrom is then deposited on the insulating layer in a similar manner to that described above. This resistor layer 62 may itself be covered (not shown) by an insulating layer or left uncovered.

Insulating spacers 60 are then deposited around the edge of the thin film resistor 62. A acrificial layer of a material which may be dissolved or otherwise removed from the finished sensor is then also deposited on the thin film resistor. The later removal of the sacrificial layer will produce a void 61 in the layered structure. Successive layers of metal 63 (e.g. chromium), PVDF 64 and metal 63 are then deposited to form a laminated piezo-electric driving element 54. One end of the driving element is connected to the column electrode and the other end connected to earth (see Figure 16a) in a manner similar to that described above. Vias 65 having an insulating lining 66 are provided therethrough.

Further insulating spacers 60 and a second sacrificial layer are then deposited in a similar manner to that described above. Successive layers of metal 63, PVDF 64 and metal 63 are then deposited to form a laminated piezo-electric sensing element 55. The sensing element has one end connected through the via in the driving element to the thin film resistor 62 which is in turn connected to scanning electrode 71 and the other end connected to the row electrode through a via 67 in the driving element (shown in dotted outline in Figure 14) and through vias in the thin film resistor and insulating layers in a manner similar to that described above. The row electrode forms the input into a sensing circuit 53. The sacrificial layers are then removed from the cell to create voids 61 or spaces between the two piezo-electric elements 54, 55 and between the driving element 54 and the thin film resistor 62.

The dimensions of the driving and sensing piezo-electric elements are selected so as to have a resonant frequency equal to that of the alternating voltage supply.

The column electrodes 68 of the sensor are all connected to an alternating voltage supply which can apply a pulse 51 of a square wave alternating voltage to the driving element 54 causing it to vibrate at its resonant frequency. The vibrating of the driving element causes the sensing element 55 to vibrate in sympathy and results in a change in the electric field produced within the

sensing element.

Contact of the sensing element by an epidermal ridge of a fingerprint pattern will dampen its vibrations and result in a change in the electric field produced in the sensing element by its piezo-electric properties. This results in different output signals between those cells actuated by contact with an epidermal ridge and those not so actuated.

The state of each cell is determined by scanning the array from, say, top left to bottom right. The addressing circuit 68 applies an addressing signal to each sensing element in turn. This addressing signal produces an output indicative of the state of the scanned cell which is monitored by the sensing circuit 51.

The entire cell is scanned to produce an output matrix of signals representing the fingerprint pattern. This may be considered to be a matrix having positions corresponding to the location of each cell within the array wherein actuated cells are represented by a ("1") (i.e. high) signal and non-actuated cells by a ("0") (i.e. low) signal.

The dimensions of the driving and sensing piezo-electric elements of the invention are selected so as to have a resonant frequency equal to the frequency of the alternating voltage supply.

The Modulus of Elasticity of the piezo-electric elements

is small compared to that of the polyimide and chromium layers;

$$E\ (\text{polyimide}) = 4 \times 10^{9}\ \text{Pa}$$
$$E\ (\text{PVDF}) = 2 \times 10^{9}\ \text{Pa}$$
$$E\ (\text{chromium}) = \leq 200 \times 10^{9}\ \text{Pa}$$

The vibrating system therefore behaves as a metal beam resting on a uniform resilient support with a stiffness approaching that of the chromium layer, but more accurately;

Bending Stiffness (E1) is given by

$$EI = (E_{CR}\ I_{CR} + E_{PVDF}\ I_{PVDF})\ \text{Pa m}^4$$

and the natural or resonant frequency (F_n) of the combined PVDF and chromium layer is given by:

$$F_n = \frac{9.55 \times 3.52}{60} \sqrt{\frac{EI}{\mu \times \ell^4}} \quad H_z$$

where: μ = mass/unit length of element

ℓ = effective length of electrode.

A sensing element having a PVDF layer 5μm thick, a chromium layer 2μm thick and an effective length of 80μm will therefore have a natural or resonant frequency of 707 kHz.

The applicant has appreciated that the effect of the applied external damping (i.e. response to contact by

epidermal ridge) to the vibrating elements diminishes greatly with higher frequencies. Consequently, if the change in output and the response to epidermal ridge contact is to be optimised, the vibrating elements must be made to resonate at as low a frequency as possible.

The controlling factor is the effective electrode length as there are restraints on the thickness of the elements. The effective length may be increased by adopting an of piezo-electric layer (or layers) (see Figures 17a to 17c) 17c having a meander configuration.

Figures 17, 18a and 19 show a further alternative construction of the sensor. Referring to Figures 17, 18a and 18c, there are no separate driving and sensing elements. A single piezo-electric element 70 having a metal layer 71 (of, say, PVDF) has a first end connected to the column electrode (i.e. input bus) through a thin film resistor, a second end connected to earth (or ground) and has a point on its length connected to the row electrode (i.e. output bus). Figure 17 does not show the connections to earth (or ground). The construction of the layers of the sensor is the same as described above.

A pulse of alternating voltage supplied to the element will cause it to vibrate at its natural or resonant frequency in the same manner as for the driving element of sensors of Figures 11, 12 and 14 described above.

This vibration will produce an output signal at the output

bus which will change when the vibrations are dampened by contact with an epidermal ridge in a similar manner to that described above.

The piezo-electric element 70 has a meander configuration so as to increase its effective length and hence reduce its natural or resonant frequency of vibration.

The configurations of Figures 18a to 18c allow one to produce a vibratable element having an effective length of approximately 600μm yet small enough to be contained within a 100μm square sensing cell. The natural or resonant frequency of the vibratable elements of Figures 18a to 18c is approximately 12.6 kHz. The meander configuration of the piezo-electric element may also be used with the sensor having upper and lower piezo-electric elements described above (Figure 14).

The card receiver (see Figure 21) has an array of thermocouples located around the receiver window 6 (see Figure 1) or the sensor (see Figure 2). The array comprises a plurality of thermocouples 20 arranged in eleven lines 19. Each thermocouple 20 produces an electrical signal in the presence of a finger. The electrical signals permit determination of the orientation and width of a finger 21 pressed over the receiver window 6.

The thermocouple array may be used both as a first low level security identification and to drive a display which

prompts the user to either reposition his finger (if incorrectly positioned) or confirm that his finger is correctly positioned on the receiver window 6.

The card receiver 5 has a set of electrical contacts inside the slot 4, which make contact with the card contacts 3 of a card inserted in the slot 4 to permit the exchange of data and power between the card receiver and the card.

A credit or bank card transaction authorisation system incorporating the present invention operates as follows:

On receipt of a new card, a user inserts the card into a card receiver and presses a selected portion of a selected finger tip against the sensor through the receiver window (see Figure 1) or on the card receiver (see Figure 2). Distinguishing features of his finger shape and print are then stored in the card microprocessor (reference data). This procedure is equivalent to signing or choosing the PIN (Personal Identification Number) for a standard credit or bank card.

The user then inserts his card into a card receiver and presses the selected portion of his selected finger onto the sensor whenever he wishes to complete a credit card or banking transaction. The sensed finger data (i.e. measured data) is compared with the stored finger data and an authorisation signal given by the card receiver if the two sets of data match.

A method of determining and comparing distinguishing finger features will now be described, by way of example, with reference to Figures 25 to 38.

In this method, the sensor output data is analysed to determine the location and distribution of ridge minutiae and ridge sweat pores within the sensed fingerprint portion and the width of the finger at one or more predetermined points. The width measurements form a first identification parameter or characteristic feature of the user. The relative positions of the ridge minutiae and ridge sweat pores of the minutiae distribution and the sweat pore distribution respectively are then stored and form the distinguishing or identifying features of a particular fingerprint pattern (see Figure 26). These form a second identification parameter or characteristic feature of the user.

The sensor output data may be represented as an output matrix of electric signals wherein those sensor cells (conductor cross-over points or vibratable sensing elements) which have been actuated by the presence or absence of contact by an epidermal ridge of a fingerprint pattern are distinguished from those sensor cells which have not been so activated (e.g. actuated cells are represented by "1" or "high" and non-actuated cells by "0" or "low".

The dimensions of the finger are characterised by analysing the output signals from the thermocouple array

to determine the outline of the finger (see Figure 27). The values of the width at two predetermined positions is used to characterise the finger outline. There are the width at 5mm below the finger tip and at 17.8mm below the finger tip.

The location of epidermal ridge sweat pores is determined by analysing the sensor output data to locate those non-actuated portions of the sensor matrix which are the same size as a ridge sweat pore and which are surrounded by actuated sensor cells (see Figures 28, 29 and 30).

The output matrix is shifted minus one sensor cell position and minus two sensor cell positions (one cell position is the distance between adjacent sensor cells ie. 100μm and is approximately equal to the size of an epidermal sweat pore) parallel to the matrix row direction to produce first and second shifted matrices respectively, and parallel to the matrix column direction to produce third and fourth shifted matrices respectively.

The first shifted matrix and the output matrix are inputted into a first EXCLUSIVE-OR operator to produce a first EXCLUSIVE-OR operator output matrix (an EXCLUSIVE-OR operation is one in which only the differences between two sets of data are stored). The first shifted matrix and the second shifted matrix are inputted into a second EXCLUSIVE-OR operator to produce a second EXCLUSIVE-OR operator output signal.

The third shifted matrix is inputted into third and fourth EXCLUSIVE-OR operators with the output matrix and fourth shifted matrix respectively to produce third and fourth EXCLUSIVE-OR operator output matrices respectively.

The four EXCLUSIVE-OR operator output matrices are grouped into two pairs and each pair inputted into first and second AND operators respectively (an AND operation is one in which only the equalities between two sets of data are stored).

The two resulting AND operator output matrices are inputted into a third AND operator. The resulting third AND operator output matrix corresponds to the ridge sweat pore distribution of sensed fingerprint pattern. This may be described as a sweat pore location matrix.

The shifting and EXCLUSIVE-OR procedure described above is equivalent to shifting the sensor output matrix plus one and minus one sensor cell position in the two orthogonal directions defined by the sensor matrix rows and columns and then inputting each of the shifted matrices into a separate EXCLUSIVE-OR operator together with the sensor output matrix. The sweat pore distribution can therefore also be determined by shifting the sensor output matrix plus one and minus one cell position in the two orthogonal directions.

The ridge minutiae locations and distribution are determined by analysing the sensor output data to locate

those points in the sensed fingerprint pattern where a ridge (ie line of activated sensor cells) or valley (ie line of sensor cells not activated) is discontinued.

The presence or otherwise of a ridge minutiae at a particular position is determined by considering the status of sensor cells contained within an analysis portion of the sensor matrix (see Figures 31 to 35). An alternative method of determining the location of ridge minutiae is described in GB-A-2243235.

After the ridge sweat pore locations have been determined the sweat pore matrix is added to the sensor output matrix. This is equivalent to filling in the non-actuated portions of the sensor output matrix and eliminates any errors that might arise by wrongly identifying sweat pores as minutiae.

Figures 31 and 32 illustrate two possible methods of determining whether an analysis portion of the sensor cell contains a ridge minutiae.

Figures 34a and 34b illustrate a ridge ending and a valley ending respectively within an analysis portion 33 of the sensor matrix. The portion 33 is defined by six rows and six columns (ie thirty-six cells). The position of a cell within the matrix portion 33 will be defined by x and y (cartesian) co-ordinates where the origin is defined by the bottom left-hand corner of the matrix portion 33.

Referring to Figure 32, the output data stream from the six rows under consideration is analysed to determine whether the cells in the central portion 31 at positions (3,3), (3,4), (4,3) and (4,4,) have either all been activated or all not been activated.

The output data stream is also analysed to determine the total number of activated cells in the thirty-six cell matrix portion 33.

If all four cells in the central portion 31 have been activated and the total number of activated cells in the six by six cell area 33 is fifteen then the central portion 31 corresponds to a ridge ending (see Figure 34a).

Alternatively, if all four cells in the central portion 31 have not been activated and the total number of activated cells in portion 33 is twenty-one then the central portion 31 corresponds to a valley ending (see Figure 34b).

The analysis is then repeated for all the six by six matrix portions contained within the sensor matrix and the distribution of ridge minutiae within the sensed fingerprint pattern determined. This may be represented as a minutiae matrix of a form similar to the sweat pore matrix. The dimensions of both the sweat pore matrix and the minutiae matrix will be the same as that of the sensor output matrix.

This is achieved (see Figure 32) by analysing the sensor

output matrix to determine all those first portions (or pixel areas) of the matrix two sensor cell positions square which have either all been actuated ("1") or all not been actuated ("0"). Then the area of the matrix surrounding any such first portions (or pixel areas) and contained within a second matrix portion six sensor cell positions square centred on the first portions is analysed to determine the number of cells therein which have been actuated ("1").

Referring to the alternative method of Figure 31, first the sensor output matrix is analysed to determine those first portions of the matrix two sensor cells square which have either all been actuated ("1") or all not been actuated ("0"). Then the area of the matrix surrounding each of these first portions is analysed to determine whether there is a rectangle of cells which have either all been actuated ("1") or all not been actuated ("0") which is continuous with one side of the first portion.

A first portion having four actuated ("1") cells contiguous on one of its sides with a rectangle of thirty two actuated ("1") cells and having its other sides surrounded by non actuated ("0") cells will indicate a ridge edging.

A first portion having four non-actuated ("0") cells contiguous on one of its sides with a rectangle of thirty-two non-actuated ("0") cells and having its other sides surrounded by actuated ("1") cells indicates a ridge

bifurcation (i.e. ridge valley ending).

The sweat pore and minutiae matrices are then analysed to produce a data stream characteristic of the fingerprint pattern.

There are a large number of ridge sweat pores and ridge minutiae on a finger tip. It will not usually be necessary to use the entire sweat pore distribution and ridge minutiae distribution to produce a data stream characteristic of a particular individual. For example, at present the Home Office consider the relative locations of five distinguishing features to be sufficient to accurately identify an individual. The size of the distributions can be reduced by considering only a selected portion or window of the sweat pore and minutiae matrices. The position of this selected portion can, for example, be defined with reference to the finger tip outline so as to ensure that the system always compares the same portion of the finger print pattern.

The sweat pore matrix is scanned row by row from top to bottom and from left to right as one would read a page of text i.e. top left to bottom right. When a sweat pore is located, the minutiae matrix is scanned in the same manner and the distances between the sweat pore and any located minutiae stored as a first number sequence in the order in which the respective minutiae are located on the minutiae matrix. The process is repeated for each sweat pore in the sweat pore matrix and the number sequences

corresponding to each sweat pore location stored as a second number sequence in the order in which the respective sweat pores were located in the sweat pore matrix. The second number sequence is a sum of the first number sequences. This second sequence is used to characterise the fingerprint pattern.

A fingerprint feature may be classified into one of seven different classifications (e.g. plain arch, radial loop, and plain whorl) according to a fingerprint classification system developed by E.R.Henry (see BYTE, October 1993, "PCs Catch Criminals Using Fingerprint Analysis"). The classification of a fingerprint pattern may be determined by analysing the rows and columns of the sensor output matrix, and diagonals at 45° thereto to calculate the values of the maximum and minimum ratios of actuated ("1") cells to non actuated ("0") cells (see Figures 36 and 37). This is a well known procedure and the fingerprint classification may be used as a further identification parameter or characteristic feature of the authorised user of the card 1.

Referring to Figure 38, the distinguishing features (ie minutiae and sweat pore distributions) of the fingerprint pattern of a selected portion of a selected finger are stored in the on-card memory of the card microprocessor 11 as a characteristic number sequence. The finger widths and fingerprint classification are also stored in the on-card memory. When the card is inserted into a card receiver and a finger pressed onto the sensor matrix, the

output data stream is latched before being communicated to a card receiver microprocessor 23 where it is processed to determine the finger widths, the fingerprint pattern, the ridge minutiae and ridge sweat pore distributions and hence to produce a characteristic number sequence (i.e. the identification parameters or user's characterising features).

The on-card memory communicates the stored identification parameters or characteristic features to the card receiver microprocessor where they are compared with the sensed identification parameters (user's characteristic). The card receiver microprocessor 23 then authorises the credit card or banking transaction if the stored and sensed sequences match, provided that there is no contrary instruction from a remote central database (eg bank customer is overdrawn). The matching of the sequences corresponds to matching stored and sensed fingerprint patterns.

The sensed and stored characteristic number sequences are compared by scanning the two sequences and determining what proportion of the two sequences are the same. This is done by looking for identical sequences in both the sensed and stored characteristic sequences. If more than a predetermined proportion of the two sequences are the same, the card receiver microprocessor authorises the transaction.

The apparatus and method described above allow one to rapidly and accurately record and/or compare distinguishing features of a fingerprint pattern.

In an alternative form of sensor, the cells are each formed by a thermocouple.

In an alternative form of card receiver, the thermocouple array may be replaced by an array of piezo-electric pressure sensors of the sort well known in the art of pressure sensors.

The card microprocessor may be replaced by a magnetic strip onto which fingerprint data translated into code has been written.

The relative capacities of the card memory, card receiver memory and remote central database may be altered, as may the relative power of the card microprocessor, card receiver microprocessor and remote central processor. For instance, the output data analysis described above may be carried out by the card microprocessor rather than the card receiver microprocessor.

The minutiae determination method described may be amended for sensor cells and/or analysis portions 33 of a different size by redefining the method parameters.

A sensor larger than the width of a fingerprint obviates the need for the thermocouple array whose function is then

carried out by the outer sensor cells of the sensor array.

Claims:

1. An identification system comprising a fingerprint sensor, the fingerprint sensor comprising an array of individually actuable sensing cells, the cells each being actuated by the pressure or absence of contact of the respective cell by the epidermal ridges of the fingerprint pattern of a finger positioned on the sensor, each actuated sensing cell contributing to a sensor output signal indicative of the relative positions of the actuated sensing cells, the identification system further comprising sensor output processing means, the sensor output processing means having means for receiving the sensor output signal and processing the sensor output signal to produce a processed signal indicative of the relative positions of distinguishing features of the sensed fingerprint pattern, the identification system further comprising memory means for storing the processed signal.

2. A verification system comprising a fingerprint sensor, the fingerprint sensor comprising an array of individually actuable sensing cells, the sensing cells each being actuated by the presence or absence of contact of the respective cell by the epidermal ridge of the fingerprint pattern of a finger positioned on the sensor, each actuated sensing cell contributing to a sensor output signal indicative of the relative positions of the actuated sensing cells, the verification system further comprising sensor output processing means, the sensor output processing means having means for receiving the

sensor output signal and processing the sensor output signal to produce a processed signal indicative of the relative positions of distinguishing features of the sensed fingerprint pattern, the verification system further comprising comparison means for comparing the processed signal with a set of allowable signals stored in the system memory means, and authorisation means for producing an authorisation signal when the processed signal matches an allowable signal.

3. A system according to claim 1 or claim 2 wherein the array of sensor cells is sufficiently fine to sense sweat pores located in epidermal ridges, the fingerprint pattern distinguishing features include sweat pores in the epidermal ridges, and the processing means comprises means for determining the relative positions of those non-actuated portions of the sensor array which are the same size as epidermal sweat pores and are surrounded by actuated sensor cells.

4. A system according to claim 3 wherein the locations of sweat pores are determined by comparing the signals from each cell or group of cells in the array with the signals from each adjacent cell or group of cells.

5. A system according to claim 4 wherein the width of a ridge sweat pore is substantially equal to a predetermined integer multiple of the distance between the centre of adjacent sensing cells of the array and the processing means comprises; latching means for latching

the sensor output signal, sensor output signal shifting means into which the sensor output signal is latched, the shifting means shifting the sensor output signal minus the predetermined integer multiple number of sensing cell positions and minus two times the predetermined integer multiple number of sensing cell positions in two orthogonal directions to produce four shifted signals, first and second shifted signals being the sensor output signal shifted minus the predetermined integer multiple number of sensing cell positions and minus two times the predetermined integer multiple number of sensing cell positions respectively in a first direction, third and fourth shifted signals being the sensor output signal shifted minus one predetermined integer multiple number of sensing cell positions and minus two times the predetermined integer multiple number of sensing cell positions respectively in a second direction orthogonal to the first direction, four EXCLUSIVE-OR operators, the first shifted signal being inputted into first and second EXCLUSIVE-OR operators together with the sensor output signal and second shifted signal respectively to produce first and second EXCLUSIVE-OR operator output signals, the third shifted signal being inputted into third and fourth EXCLUSIVE-OR operators together with the sensor output signal and fourth shifted signal respectively to produce third and fourth EXCLUSIVE-OR operator output signals, three AND operators, two of the EXCLUSIVE-OR operator output signals being inputted into a first AND operator and the other two EXCLUSIVE-OR operator output signals being inputted into a second AND operator, the output

signals from the first and second AND operators being inputted into a third AND operator to produce a processing means output signal indicative of those epidermal sweat pores located in epidermal ridges.

6. A system according to claim 5 wherein the distance between the centre of adjacent sensing cells is substantially equal to the width of a ridge sweat pore.

7. A system according to claim 5 wherein the sensing cells are arranged in a plurality of parallel rows and a plurality of parallel columns orthogonal to the sensing cell rows, and the sensor output signal is shifted parallel to the directions of the sensing cell rows and sensing cell columns.

8. A system according to any of claims 1 to 7 wherein the array of sensor cells is sufficiently fine to sense epidermal ridges and epidermal valleys, the fingerprint pattern distinguishing features include epidermal ridge minutiae and the processing means comprises; monitoring means for monitoring whether a first portion of the sensor array has been actuated, the breadth of the first sensor portion being equal to or less than the width of an epidermal ridge, the monitoring means producing a monitoring means output signal indicative of the status of the individually actuable sensing cells within the first sensor portion, addition means for determining the total number of actuated sensing cells within a second portion of the sensor pattern, the breadth

of the second sensor portion being equal to or less than the distance separating the centre-lines of adjacent epidermal ridges and having the first sensor portion at its centre, the addition means producing an addition means output signal indicative of the number of actuated sensing cells within the second sensor portion,

second memory means for storing sets of monitoring means output signals and addition means output signals, each set indicative of a monitoring means output signal and an addition means output signal which when produced at the same time by the first and second portions of a sensor array having a finger positioned thereon correspond to a ridge minutiae located at the first sensor portion,

second comparison means for comparing the monitoring means output signal and addition means output signals to the sets of signals stored in the second memory means, the second comparison means producing a second comparison means output signal indicative of the presence of a ridge minutiae at the first sensor portion when the monitoring means output signal and addition means output signal match one of the sets of signals stored in the memory means.

9. A system according to claim 8 wherein the centres of adjacent individually actuable sensing cells are substantially 100 μm apart, the first sensor portion comprises four sensing cells forming a square substantially 200 μm in breadth, the second sensor portion comprises thirty-six sensing cells forming a square

substantially 600 μm in breadth, a first set and a second set of signals are stored in the second memory means, the first set of signals comprising a first signal representing a first sensor portion having four actuated cells and a second signal representing a second sensor portion having fifteen actuated cells, the second set of signals comprising a third signal representing a first sensor portion having no actuated cells and a fourth signal representing a second sensor portion having twenty-one actuated cells.

10. A system according to claims 3 and 8 wherein the processing means includes calculating means for calculation of the distances between epidermal ridge sweat pores and epidermal ridge minutiae.

11. A system according to any of the preceding claims wherein the sensor output processing means includes means for calculating in a predetermined order the distances from each of a first set of distinguishing features of the sensed fingerprint pattern to each of a second set of distinguishing features of the sensed fingerprint pattern to produce an ordered sequence of the calculated distances.

12. A system according to claim 11 wherein the first set of distinguishing features comprises epidermal ridge sweat pores and the second set of distinguishing features comprises epidermal ridge minutiae.

13. A verification system according to claim 11 or claim 12 wherein the ordered sequence is compared to a stored ordered sequence, and an authorisation signal produced when more than a predetermined portion of the first ordered sequence matches the stored ordered sequence.

14. An identification method for use with a fingerprint sensor, the fingerprint sensor comprising an array of individually actuable sensing cells, the sensing cells each being actuated by the presence or absence of contact of the respective cell by the epidermal ridges of the fingerprint pattern of a finger positioned on the sensor, each actuated sensing cell contributing to a sensor output signal indicative of relative positions of the actuated sensing cells, the identification method comprising the steps of processing the sensor output signal to produce a processed signal indicative of the relative positions of distinguishing features of the sensed fingerprint pattern, and then storing the processed signal in a memory means.

15. A verification method for use with a fingerprint sensor, the fingerprint sensor comprising an array of individually actuable sensing cells, the sensing cells each being actuated by the pressure or absence of contact of the respective cell by the epidermal ridge of the fingerprint pattern of a finger positioned on the sensor, each actuated sensing cell contributing to a sensor output signal indicative of the relative positions

of the actuated sensing cells, the verification method comprising the steps of processing the sensor output signal to produce a processed signal indicative of the relative positions of distinguishing features of the sensed fingerprint pattern, comparing the processed signal with a set of allowable signals stored in a memory means, and producing an authorisation signal when the processed signal matches an allowable signal.

16. A method according to claim 13 or claim 14 wherein the distinguishing features include sweat pores located in epidermal ridges.

17. A method according to claim 15 wherein the processing means determines the relative positions of those non-actuated portions of the sensor pattern which are the same size as epidermal sweat pores and are surrounded by actuated sensing cells.

18. A method according to claim 17 wherein the locations of sweat pores are determined by comparing the signals from each cell or group of cells in the array with the signals from each adjacent cell or group of cells.

19. A method according to claim 15 comprising latching the sensor output signal, shifting the latched sensor output signal minus one times the number of sensing cell positions substantially equal to the width of a sweat pore and minus two times the number of sensing cell positions substantially equal to the width of a sweat pore

in two orthogonal directions to produce four shifted signals, first and second shifted signals being the sensor output signal shifted minus one times the number of sensing cell positions substantially equal to the width of a sweat pore and minus two times the number of sensing cell positions substantially equal to the width of a sweat pore respectively in a first direction, third and fourth shifted signals being the sensor output signal shifted minus one times the number of sensing cell positions substantially equal to the width of a sweat pore and minus two sensing cell positions substantially equal to the width of a sweat pore respectively in a second direction orthogonal to the first direction, inputting the first shifted signal into first and second EXCLUSIVE-OR operators together with the sensor output signal and second shifted signal respectively to produce first and second EXCLUSIVE-OR operator output signals, inputting the third shifted signal into third and fourth EXCLUSIVE-OR operators together with the sensor output signal and fourth shifted signal respectively to produce third and fourth EXCLUSIVE-OR operator output signals, inputting two of the EXCLUSIVE-OR operator output signals into a first AND operator to produce a first AND operator output signal, inputting the remaining two EXCLUSIVE-OR operator output signals into a second AND operator to produce a second AND operator output signal and then inputting the first and second AND operator output signals into a third AND operator to produce a signal indicative of those sweat pores located in epidermal ridges.

20. A method according to claim 19 wherein the width of a sweat pore is substantially equal to the distance between the centre at adjacent sensing cells.

21. A method according to any of claims 13 to 17 wherein the distinguishing features include epidermal ridge minutiae.

22. A sensor comprising an array of individually actuable sensing cells and a resiliently deformable membrane defining a sealed space above the individually actuable sensing cells, wherein the sealed space is entirely filled with a pre-selected volume of a substantially incompressible fluid and the individually actuable cells are actuated by the deformation of the membrane to produce output signals representative of those sensing cells which have been actuated.

23. A sensor according to claim 22, wherein the undeformed membrane is 5 to 20 μm thick, preferably 5 to 10 μm thick.

24. A sensor according to claim 23, wherein the incompressible fluid is a silicone liquid.

25. A sensor according to claim 22, wherein the membrane periphery is fixed to a resiliently deformable support.

26. A fingerprint sensor comprising an array of

individually actuable sensing cells, wherein the cells each include a vibratable sensing element responsive to the presence or absence of contact of the cell by a fingerprint epidermal ridge and driving means for vibrating the sensing element, and the sensor further comprises detection means responsive to the extent of vibration of each of the sensing elements to produce output signals distinguishing these elements contacted by an epidermal ridge from those not so contacted.

27. A fingerprint sensor according to claim 26 wherein the driving means comprises means for supplying a driving signal to the sensing element and the sensing element vibrates when the signal is supplied thereto.

28. A fingerprint sensor according to claim 26 wherein the sensing element is a beam or a resilient support.

29. A fingerprint sensor according to claim 27 wherein the driving signal is an alternating voltage and the sensing element includes a piezo-electric material.

30. A fingerprint sensor according to claim 27 wherein the driving signal is supplied by a vibrating driving element located close to the sensing element causing it to vibrate in sympathy.

31. A fingerprint sensor according to claim 30 wherein the driving element includes a piezo-electric

material and the driving means includes means for applying an alternating voltage to the driving element.

32. A fingerprint sensor according to claim 30 wherein the sensing element includes a piezo-electric material.

33. A fingerprint sensor according to claim 27 wherein the driving signal is an oscillating signal whose frequency is substantially equal to the resonant frequency of the vibratable sensing element.

34. A fingerprint sensor according to claims 29 or 32 wherein the detection means comprises means responsive to the electric field in the sensing element.

35. A fingerprint sensor according to claim 34 wherein a first input end of the sensing element is connected to a source of alternating voltage, a second end of the sensing element is connected to earth, and the detection means is connected to the sensing element at a point between the first and second ends of the sensing element.

36. A fingerprint sensor according to claim 26 wherein the cells are arranged in a plurality of rows and columns and the driving means pulse each column in turn and the detection means read each cell output row by row.

37. A fingerprint sensor according to claims 31, 32

and 34 wherein the driving element has a first end connected to an alternating voltage supply and a second end connected to earth and the sensing element is connected to an output.

38. A fingerprint sensor according to claim 37 wherein the driving and sensing elements are distinct, interdigitated fork-shaped elements.

39. A fingerprint sensor according to claim 37 wherein the driving and sensing elements are distinct elements, the sensing element is located above the driving element and separated therefrom.

40. A fingerprint sensor according to any of claims 26 to 39 wherein the sensing element includes a layer of a metal.

41. A fingerprint sensor according to any of claims 31, 32 or 37 wherein the driving element includes a layer of a metal.

42. A sensor according to claim any of claims 22 to 41, wherein the sensor is a fingerprint sensor and forms part of an electric circuit on a plastics card, and the card electric circuit further comprises a plurality of discrete sensor input components for supplying power to the sensor, and sensor output components for receiving the sensor output signals and electrical contacts for supplying power to and communicating with the card

circuit.

43. A sensor according to claim 42 wherein each said card circuit component is located near the card neutral axis of bending.

44. A sensor according to claim 42 wherein the card circuit is supported on a support sheet having a modulus of elasticity higher than that of the plastics carrier.

45. A sensor according to claim 42 wherein the ratio of the modulus of elasticity of the support sheet to the modulus of elasticity of the plastics carrier is in the range 100:1 to 10:3.

46. A sensor according to claim 44 wherein the support sheet is an anodised nickel layer coated with a thin layer of polyimide.

47. A sensor according to any of claims 42 to 46 wherein each sensor input component or output component is supported near its centre by soft solder pads which connect each component to the card circuit.

48. An identification system including a sensor according to any of claims 42 to 48 and further comprising a card receiver, the card receiver having a slot for receiving the card, electrical contacts in the slot for connecting with the card electrical contacts of the card and sensor access means allowing a portion of a finger to

be positioned on the sensor of a card located in the card receiver slot.

49. An identification system according to claim 48 wherein the sensor access means has an array of thermocouples arranged around the perimeter of the access means.

50. An identification system according to claim 48 wherein either or both of the card or card receiver further comprise data processing means.

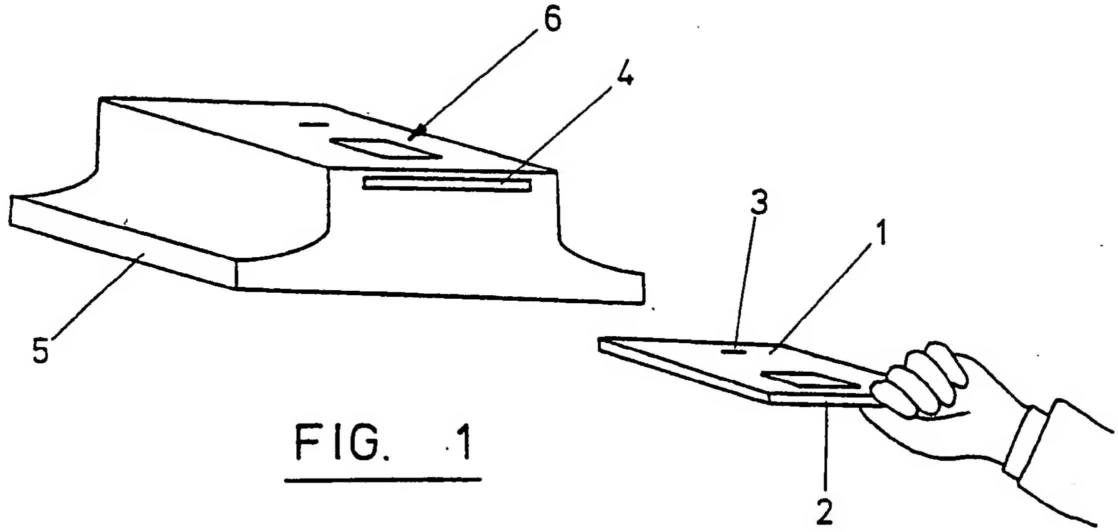

FIG. 1

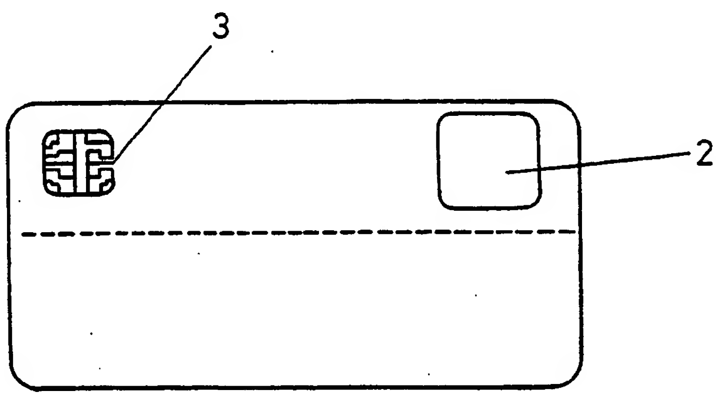

FIG. 3

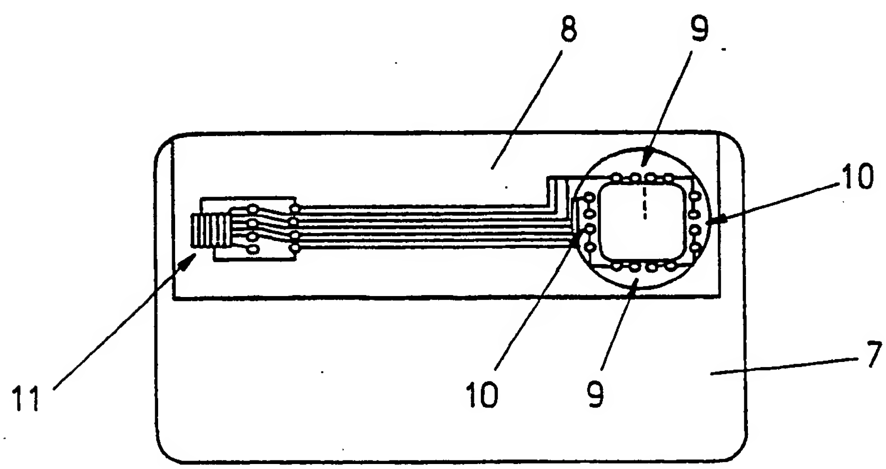

FIG. 4

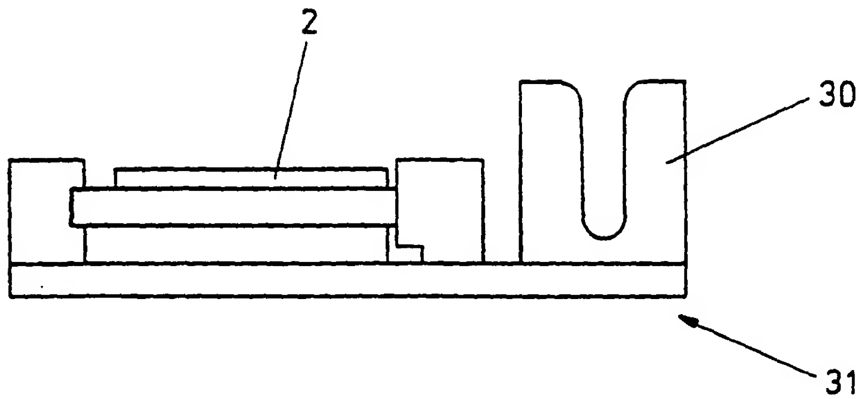

FIG. 2(a)

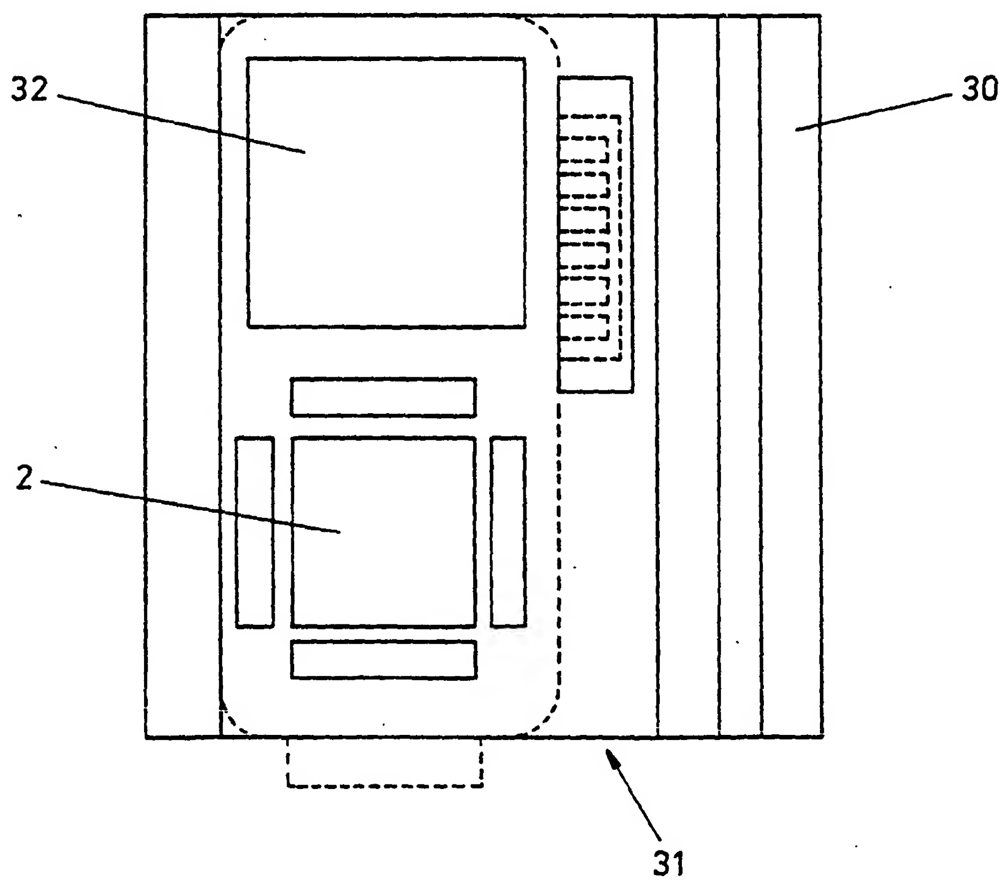

FIG. 2(b)

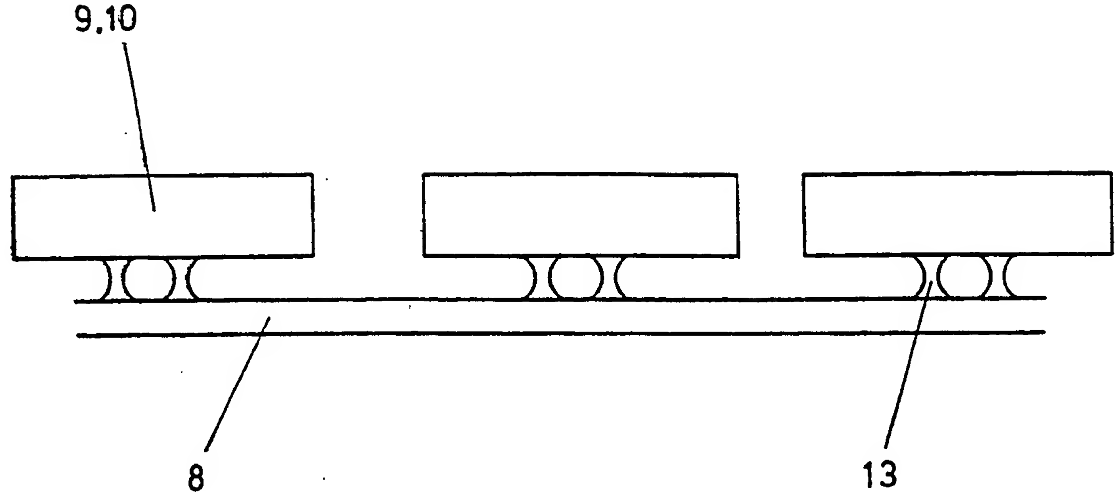

FIG. 5

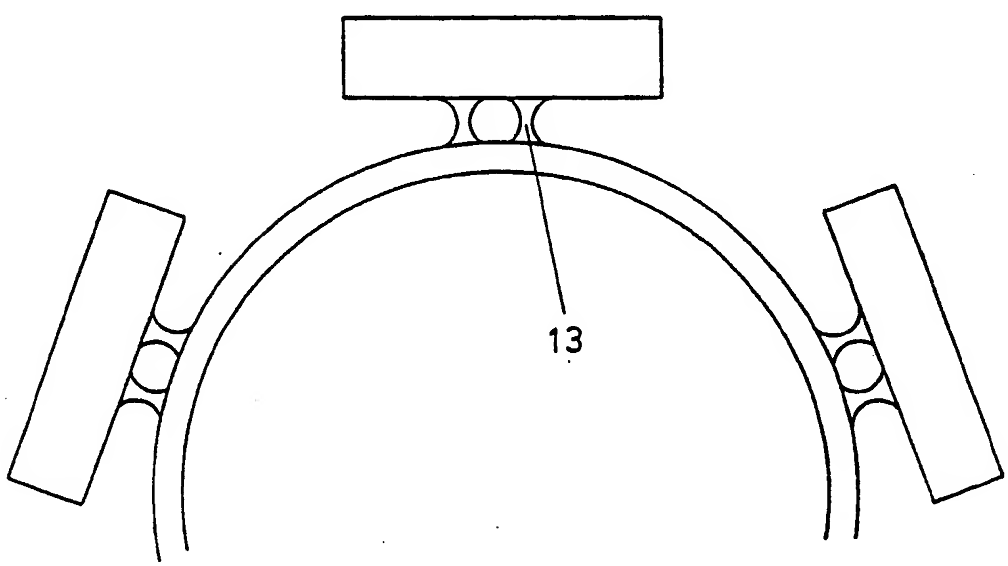

FIG. 6

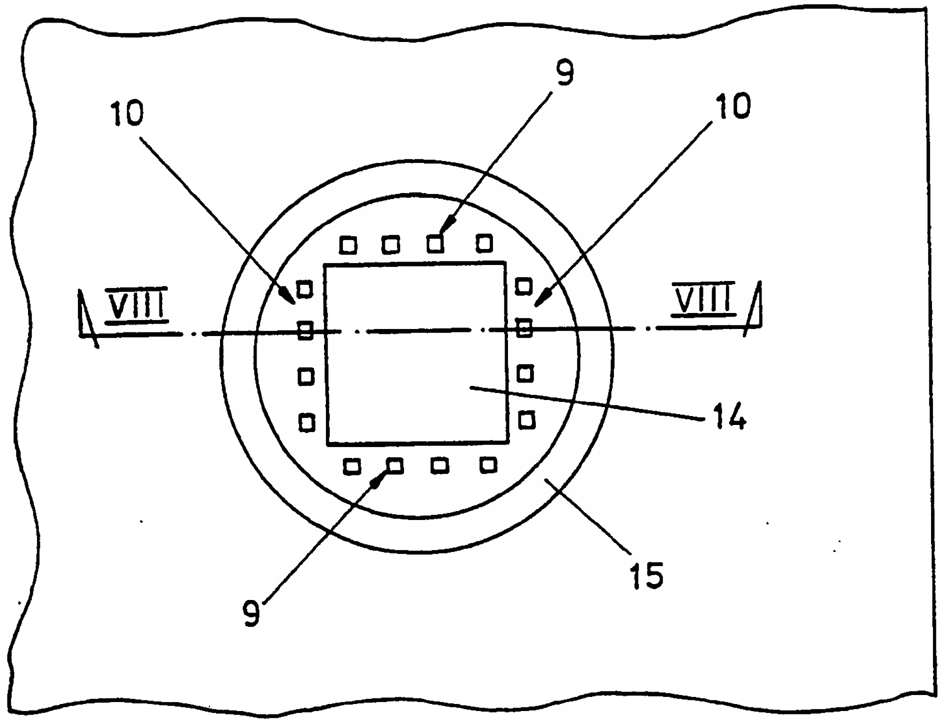

FIG. 7

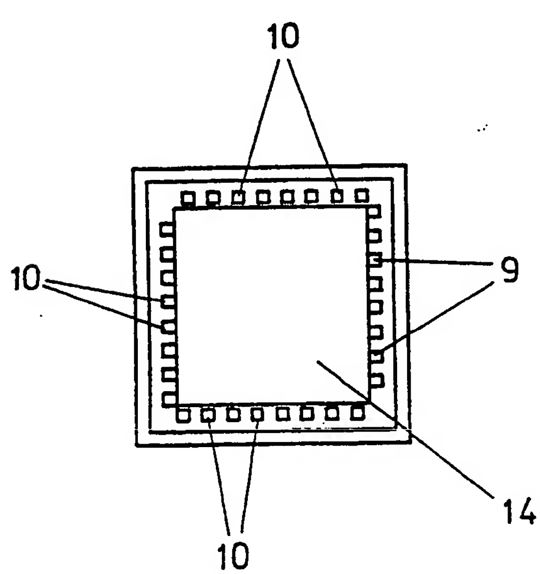

FIG. 8

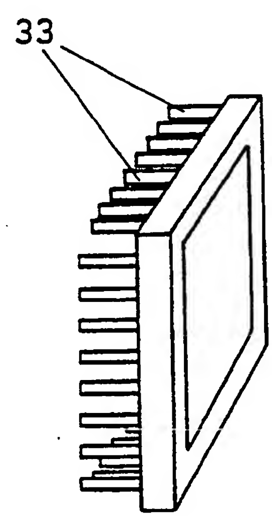

FIG. 9

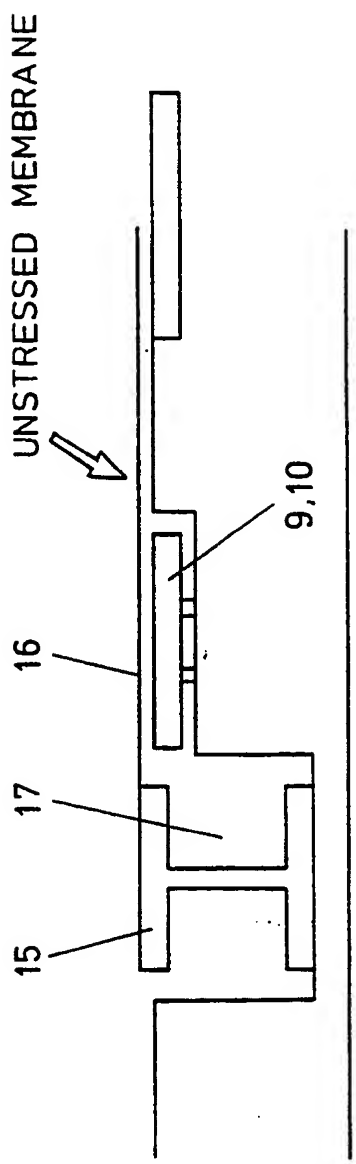

FIG. 10(a)

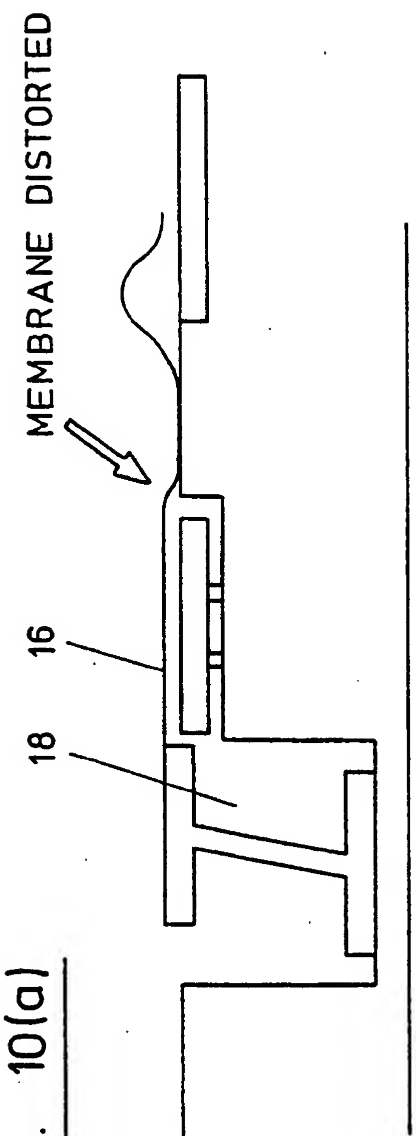

FIG. 10(b)

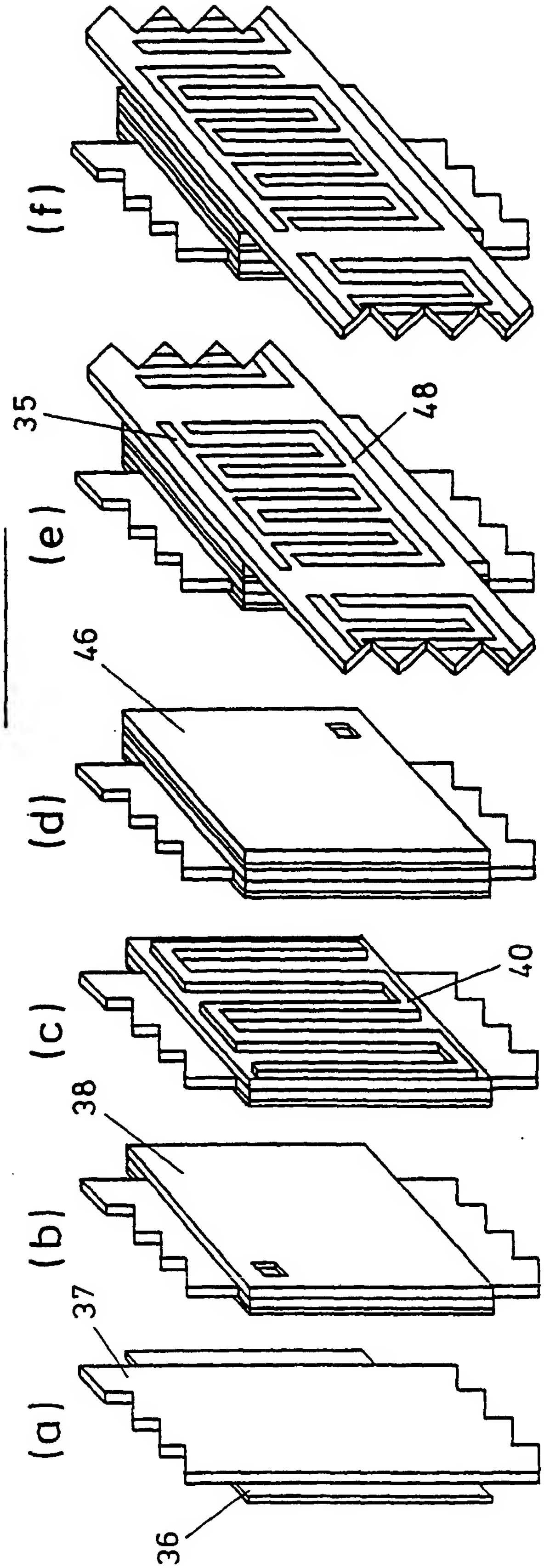

FIG. 12

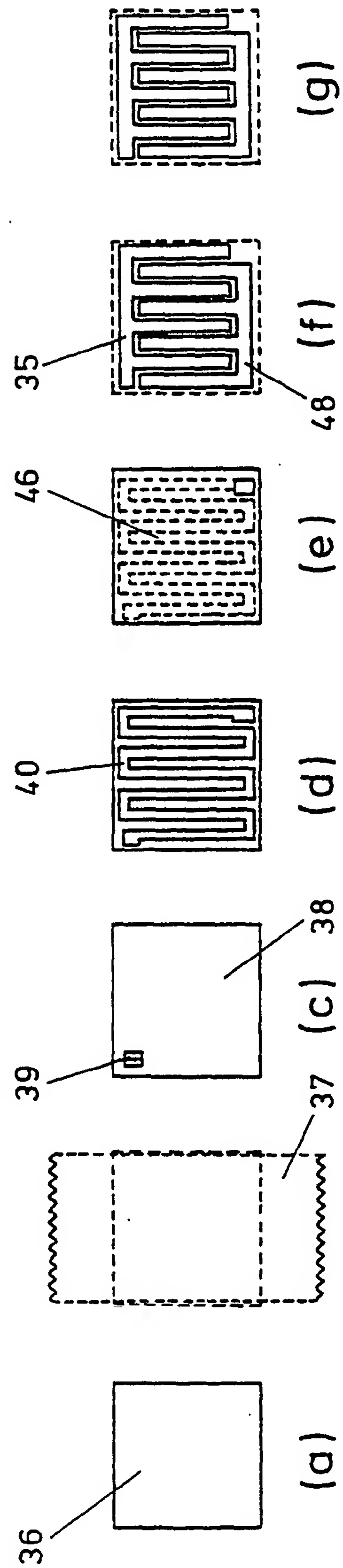

FIG. 11

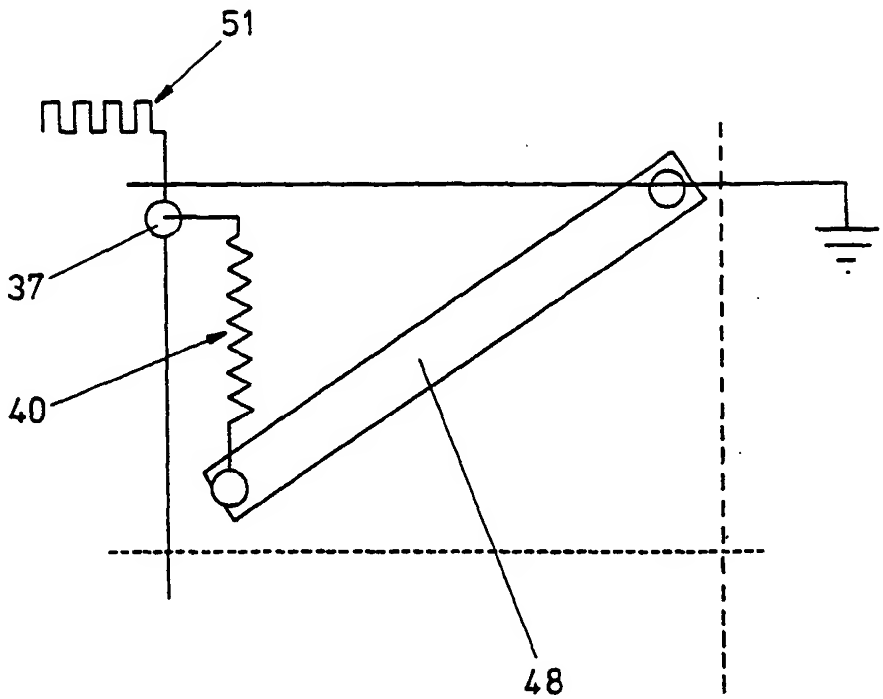

FIG. 13(a)

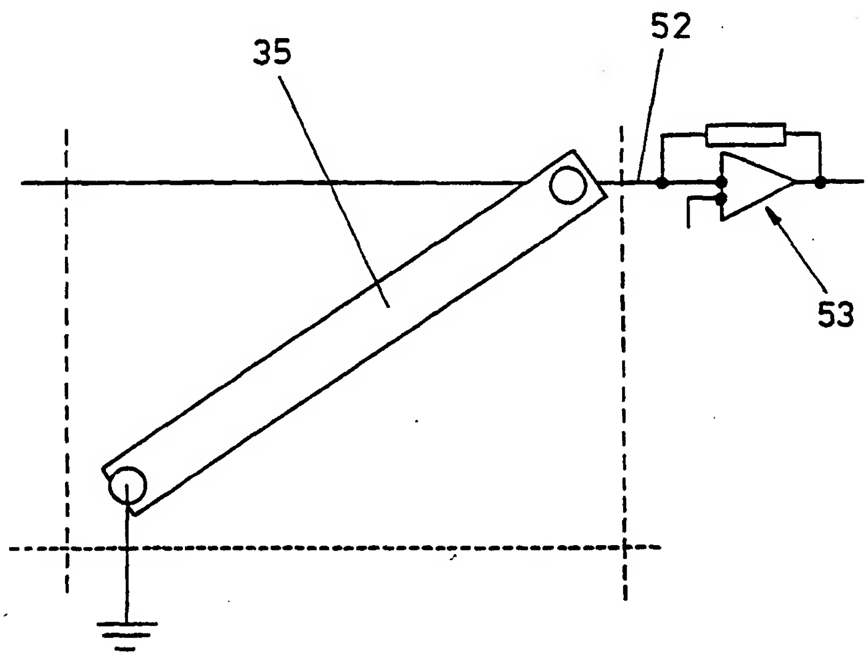

FIG. 13(b)

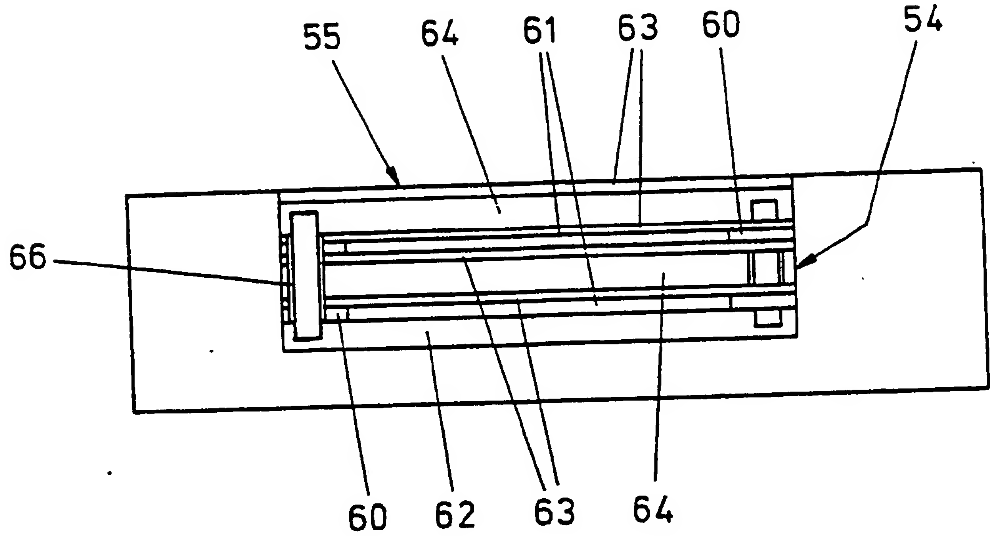

FIG. 14

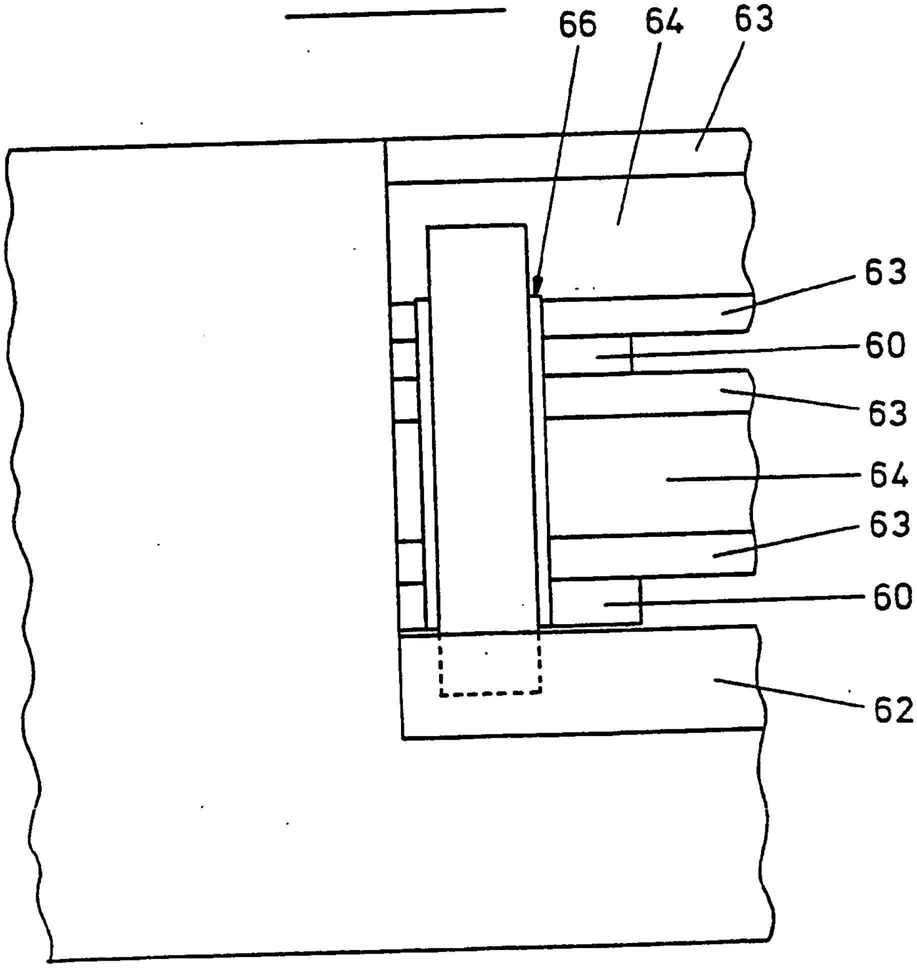

FIG. 15

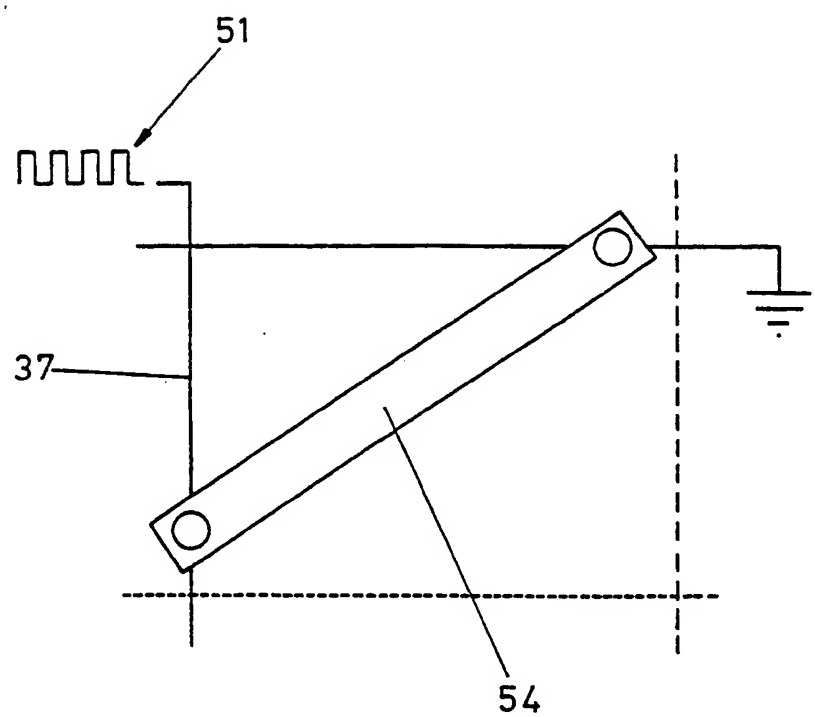

FIG. 16(a)

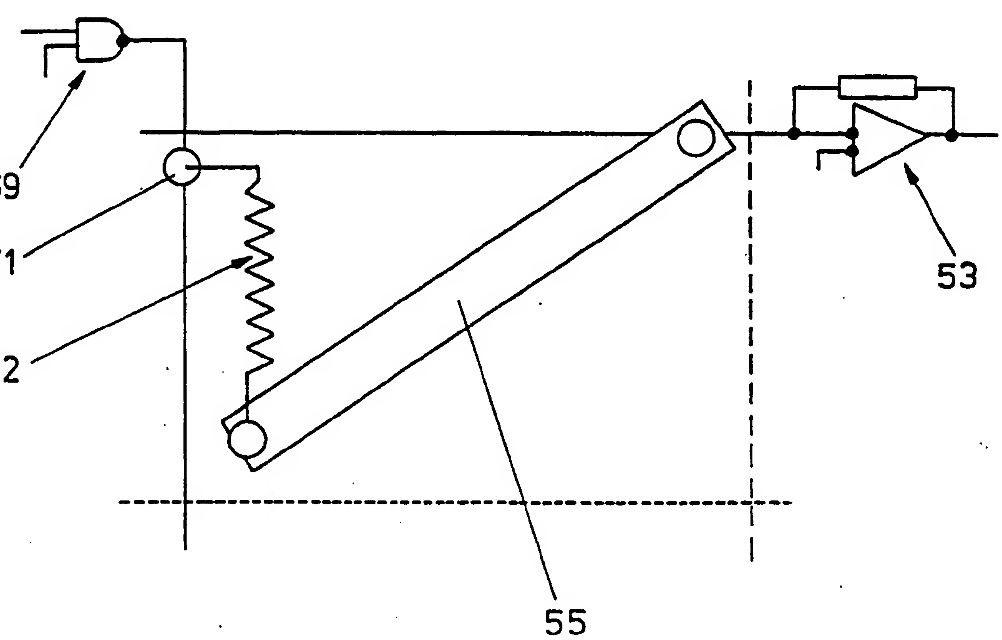

FIG. 16(b)

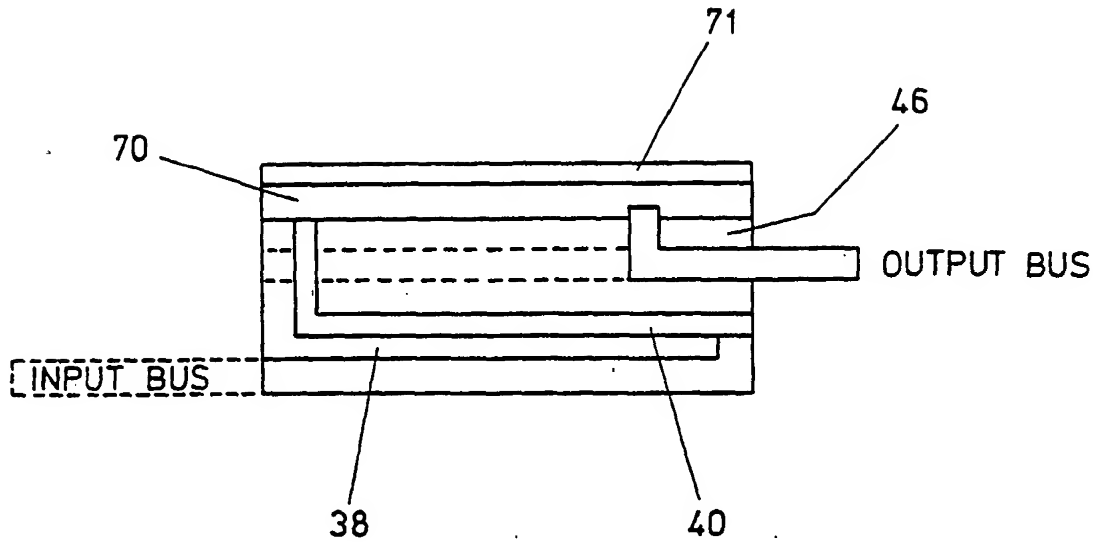

FIG. 17

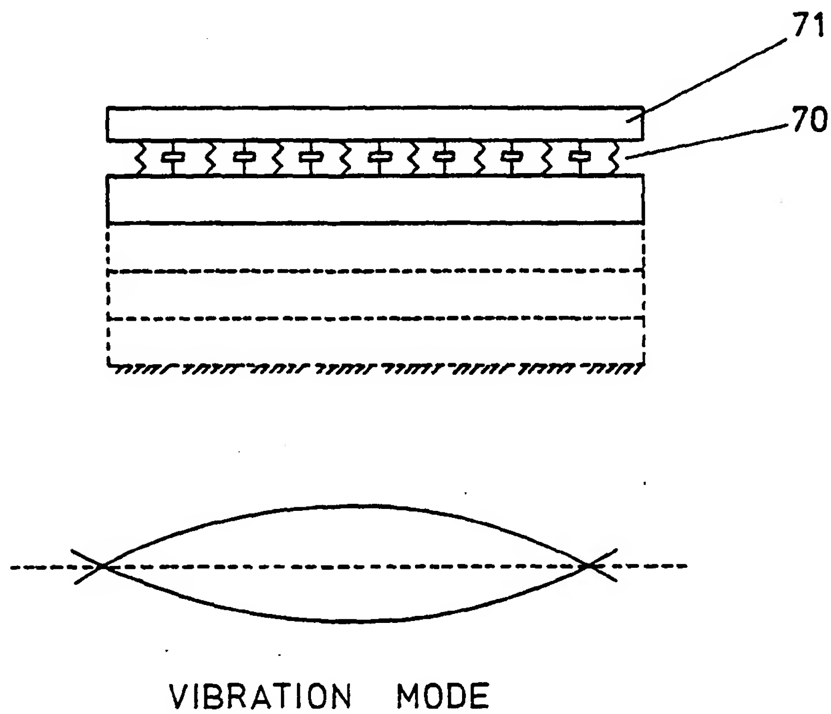

FIG. 19

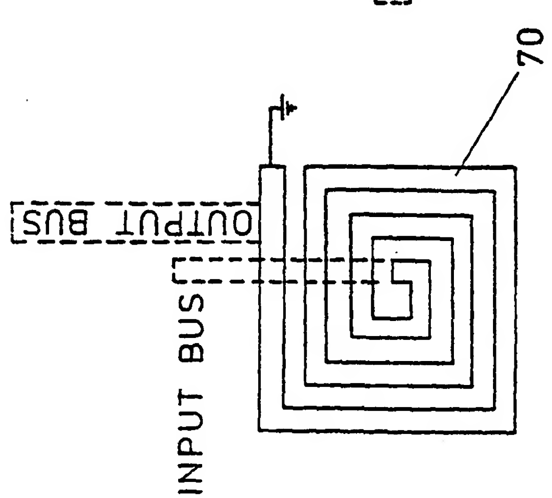

FIG. 18(a)

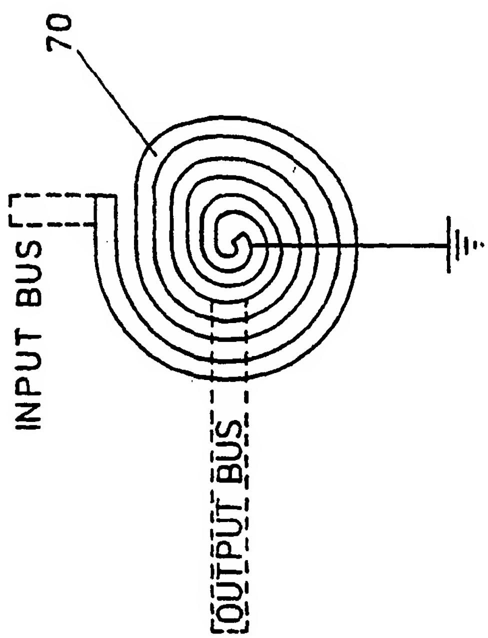

FIG. 18(b)

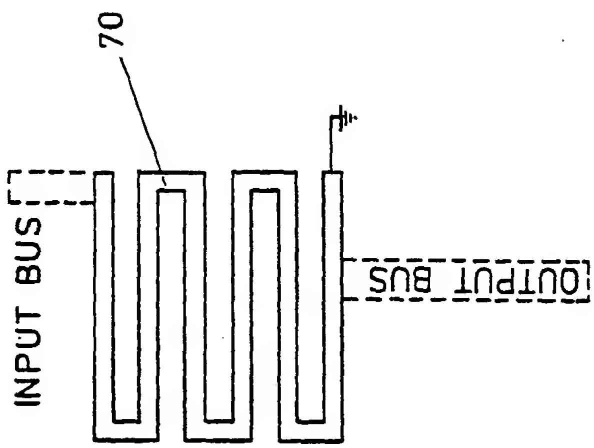

FIG. 18(c)

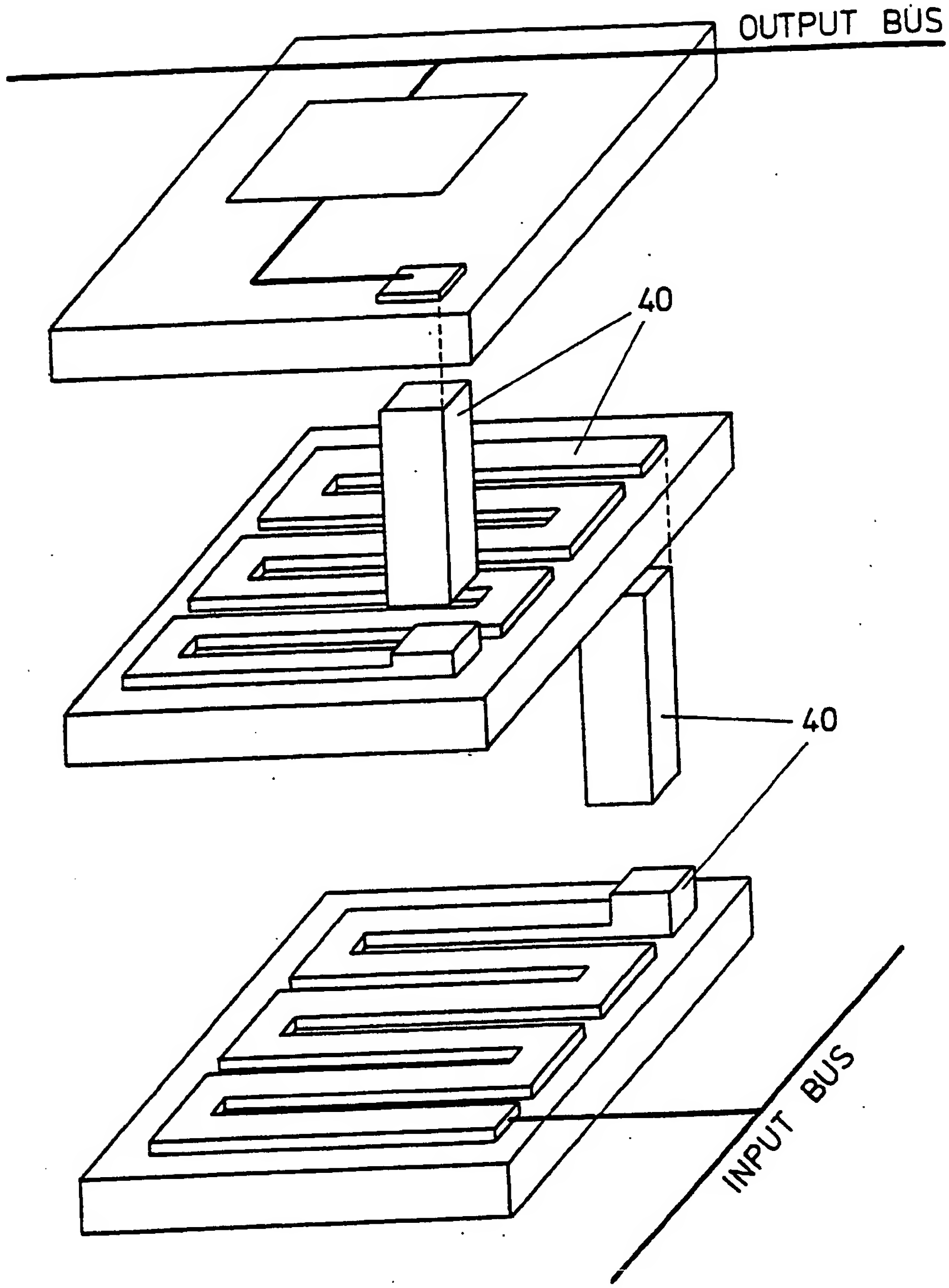

FIG. 20

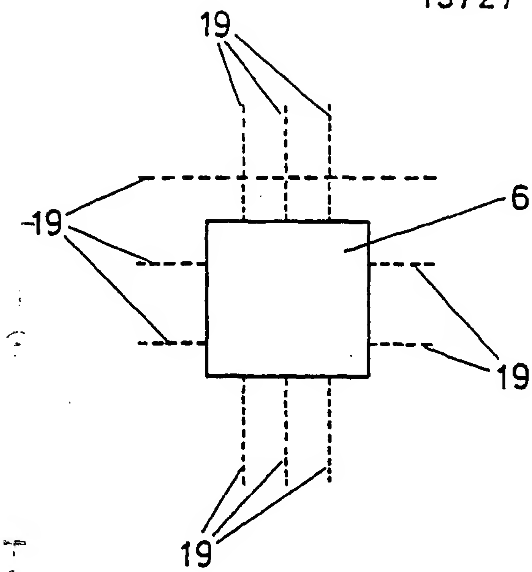

FIG. 21

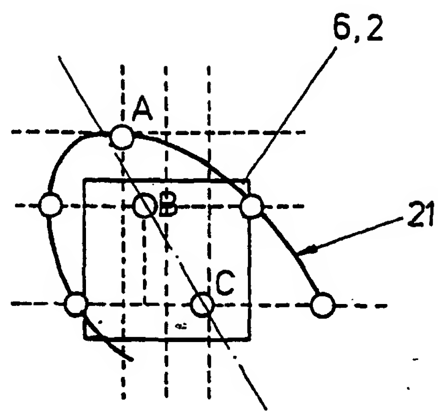

FIG. 22

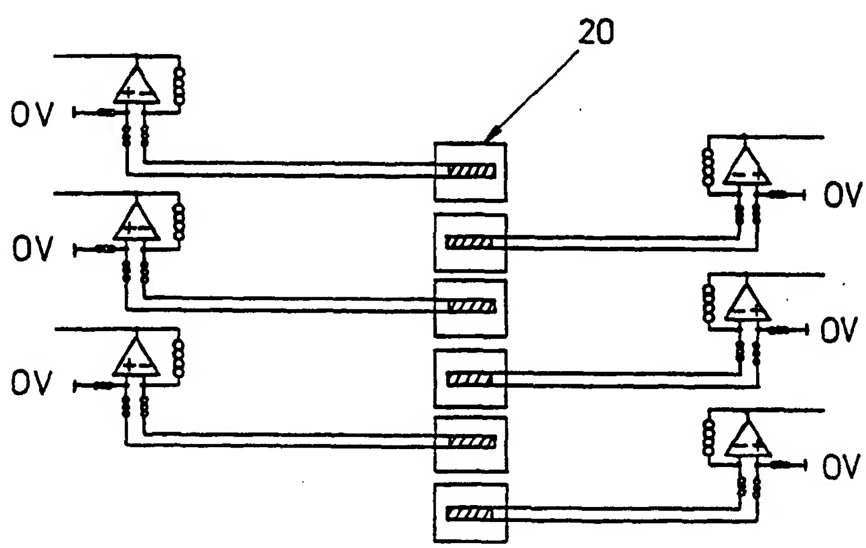

FIG. 23

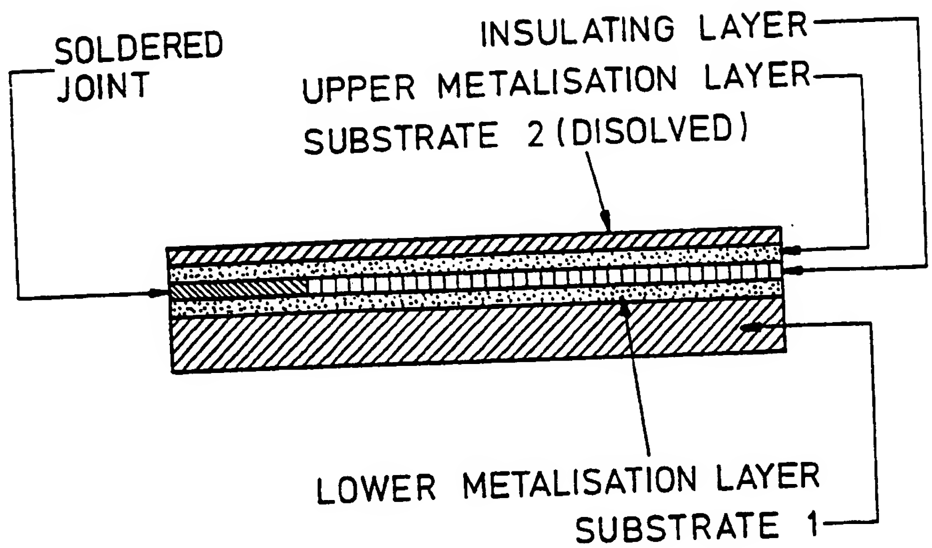
SOLDERED JOINT
INSULATING LAYER
UPPER METALISATION LAYER
SUBSTRATE 2 (DISOLVED)
LOWER METALISATION LAYER
SUBSTRATE 1

FIG. 24

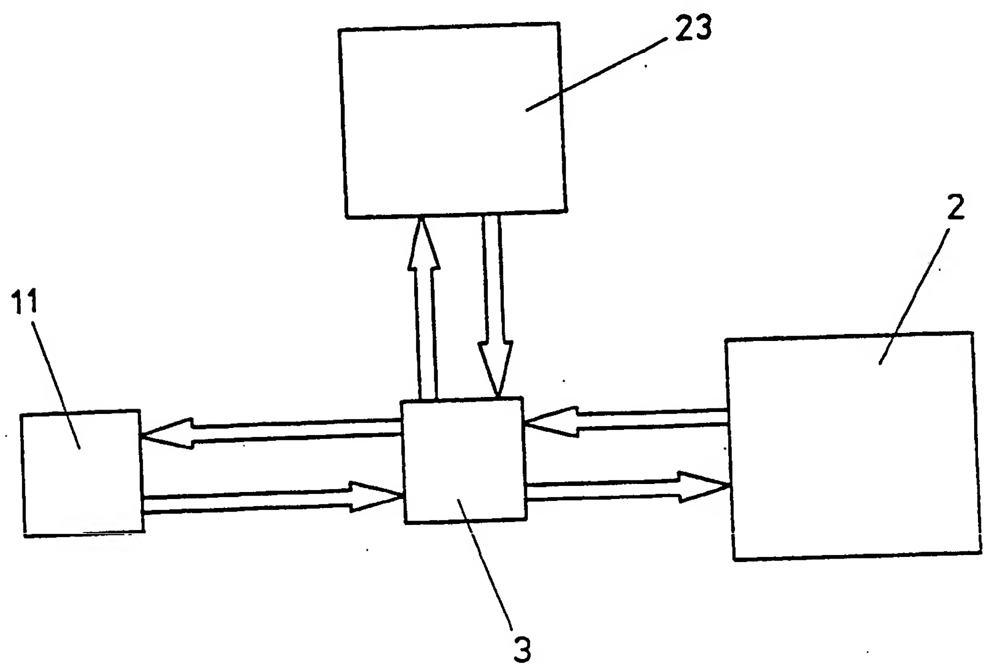
23
2
11
3

FIG. 25

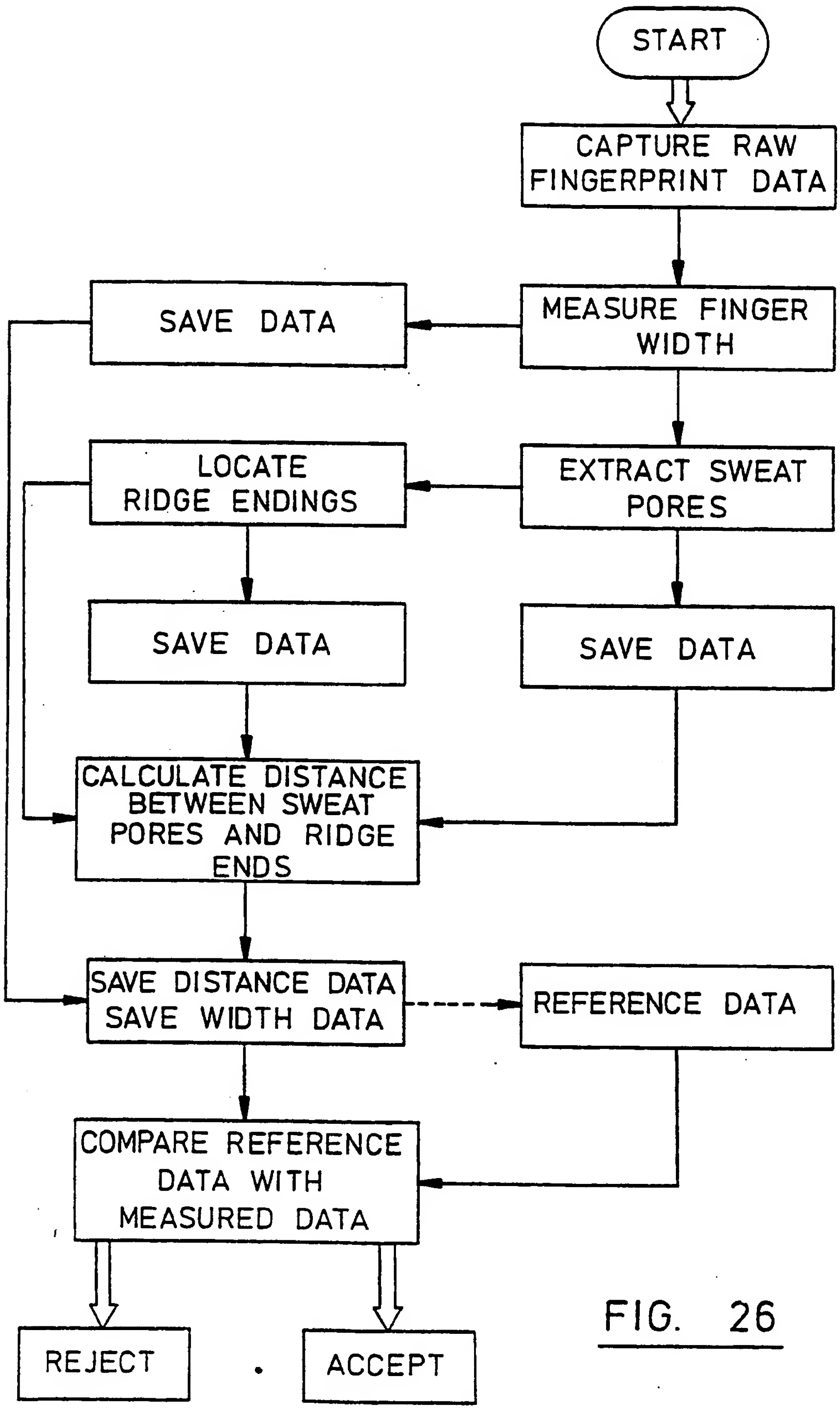
START
CAPTURE RAW FINGERPRINT DATA
MEASURE FINGER WIDTH
SAVE DATA
EXTRACT SWEAT PORES
LOCATE RIDGE ENDINGS
SAVE DATA
SAVE DATA
CALCULATE DISTANCE BETWEEN SWEAT PORES AND RIDGE ENDS
SAVE DISTANCE DATA
SAVE WIDTH DATA
REFERENCE DATA
COMPARE REFERENCE DATA WITH MEASURED DATA
REJECT
ACCEPT

FIG. 26

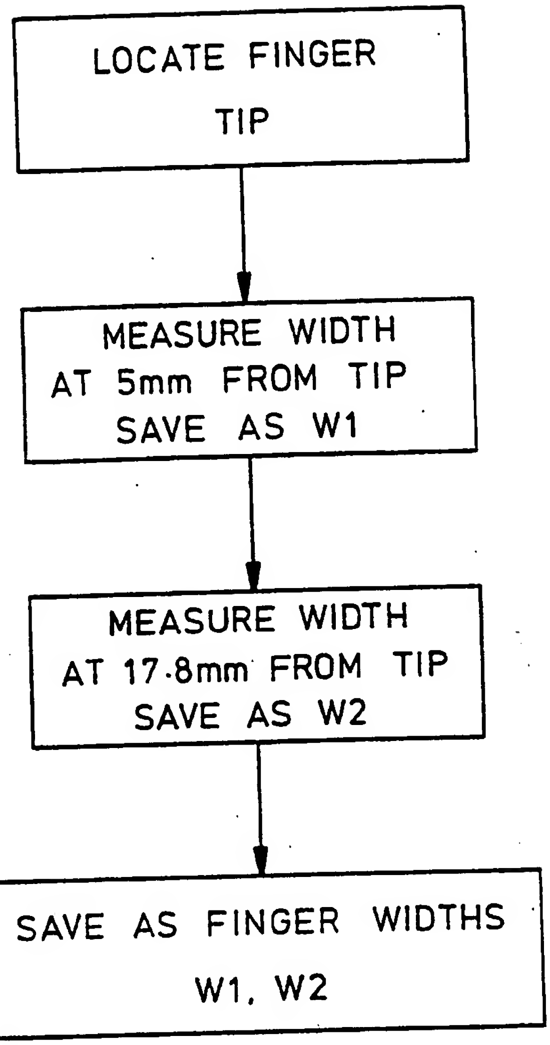
LOCATE FINGER TIP
MEASURE WIDTH AT 5mm FROM TIP SAVE AS W1
MEASURE WIDTH AT 17·8mm FROM TIP SAVE AS W2
SAVE AS FINGER WIDTHS W1, W2

FIG. 27

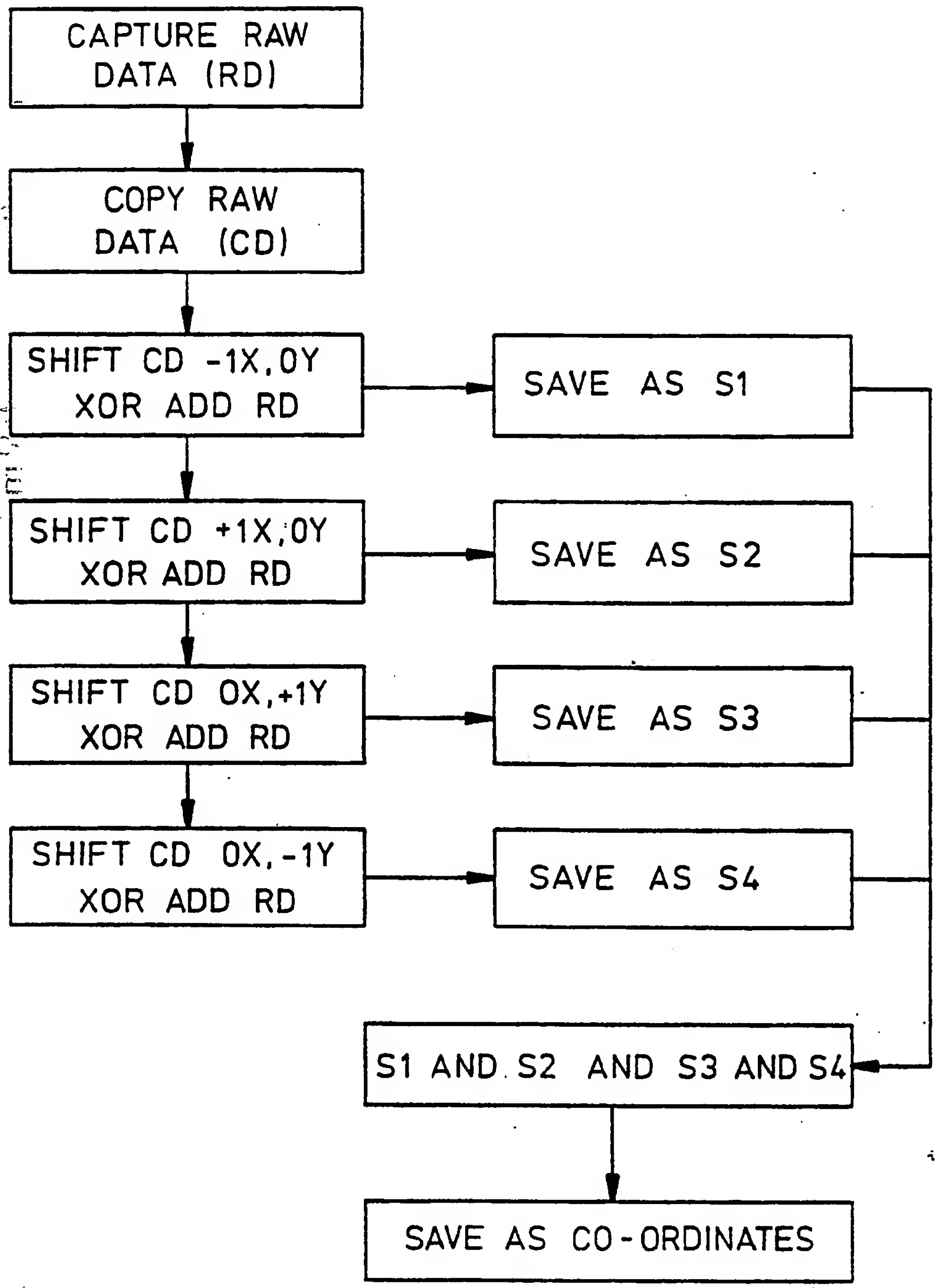
CAPTURE RAW DATA (RD)
COPY RAW DATA (CD)
SHIFT CD -1X,0Y XOR ADD RD
SAVE AS S1
SHIFT CD +1X,0Y XOR ADD RD
SAVE AS S2
SHIFT CD 0X,+1Y XOR ADD RD
SAVE AS S3
SHIFT CD 0X,-1Y XOR ADD RD
SAVE AS S4
S1 AND S2 AND S3 AND S4
SAVE AS CO-ORDINATES

FIG. 28

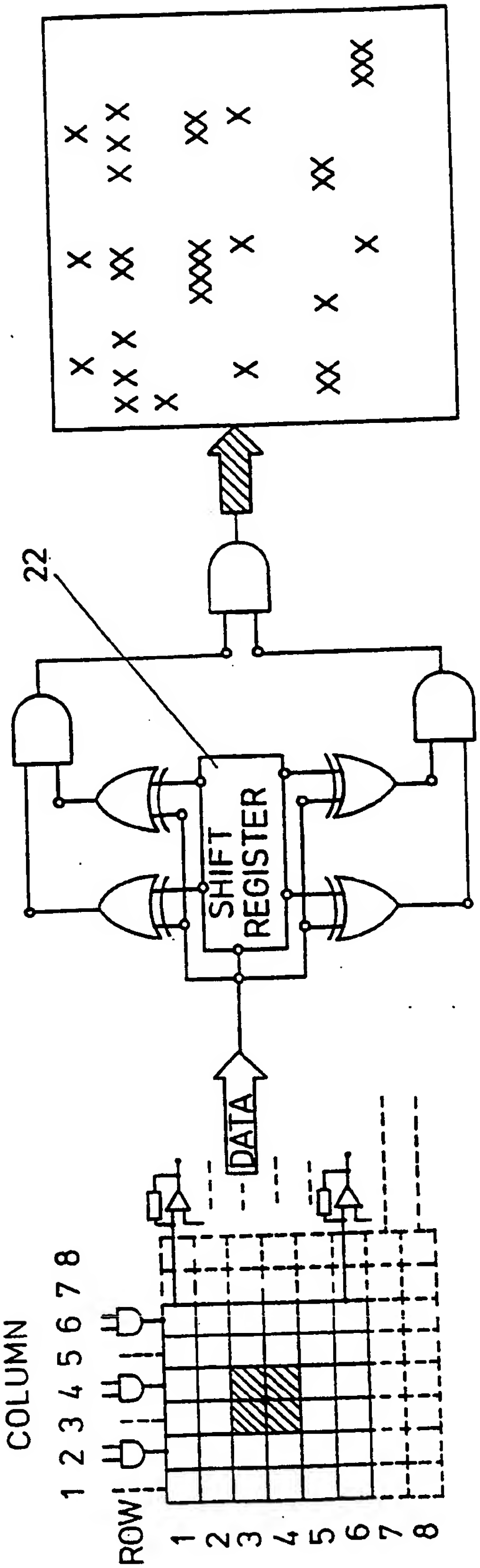

FIG. 29

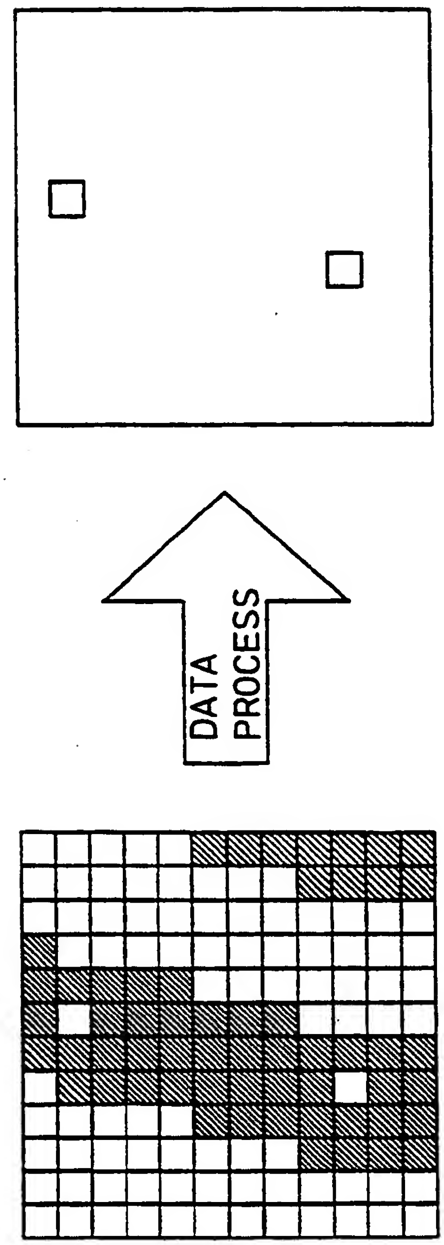

FIG. 30

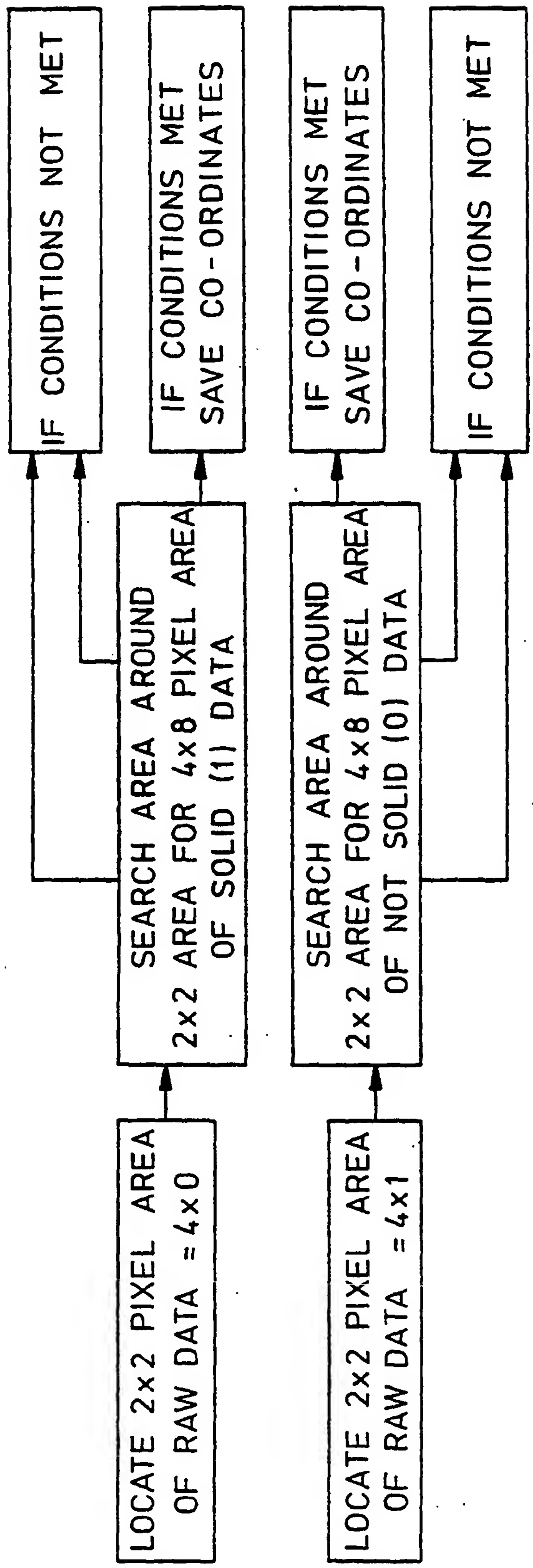
LOCATE 2x2 PIXEL AREA OF RAW DATA =4x0
LOCATE 2x2 PIXEL AREA OF RAW DATA =4x1
SEARCH AREA AROUND 2x2 AREA FOR 4x8 PIXEL AREA OF SOLID (1) DATA
SEARCH AREA AROUND 2x2 AREA FOR 4x8 PIXEL AREA OF NOT SOLID (0) DATA
IF CONDITIONS NOT MET
IF CONDITIONS MET SAVE CO-ORDINATES
IF CONDITIONS MET SAVE CO-ORDINATES
IF CONDITIONS NOT MET

FIG. 31

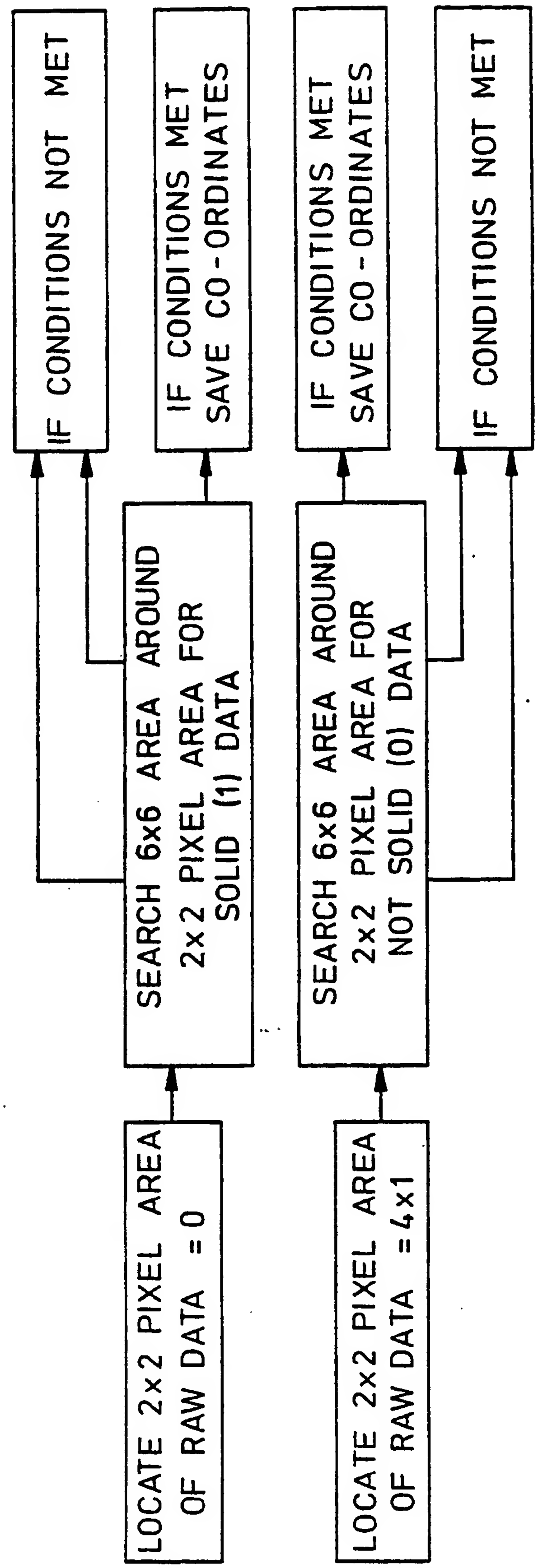
LOCATE 2x2 PIXEL AREA OF RAW DATA =0
SEARCH 6x6 AREA AROUND 2x2 PIXEL AREA FOR SOLID (1) DATA
IF CONDITIONS NOT MET
IF CONDITIONS MET SAVE CO-ORDINATES
LOCATE 2x2 PIXEL AREA OF RAW DATA =4x1
SEARCH 6x6 AREA AROUND 2x2 PIXEL AREA FOR NOT SOLID (0) DATA
IF CONDITIONS MET SAVE CO-ORDINATES
IF CONDITIONS NOT MET

FIG. 32

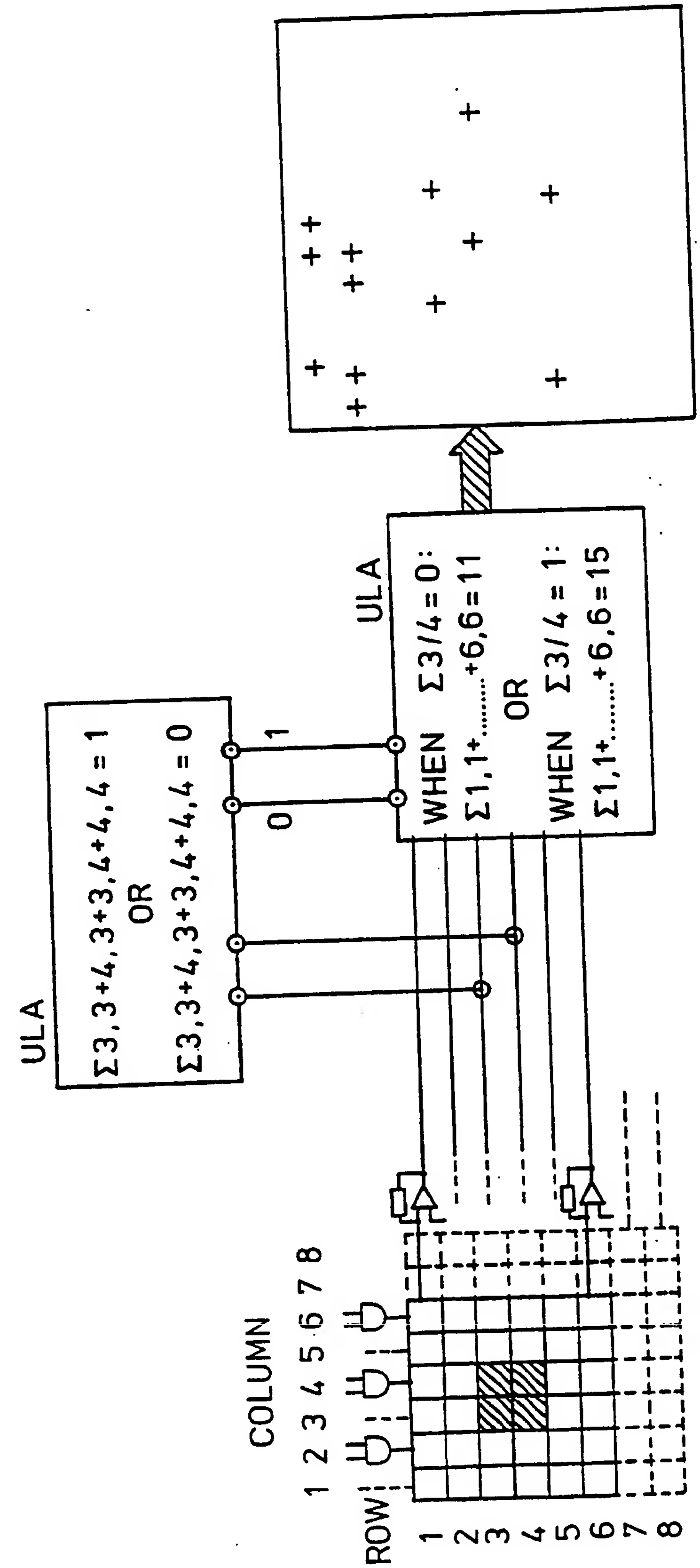
ULA
Σ3,3+4,3+3,4+4,4 = 1
OR
Σ3,3+4,3+3,4+4,4 = 0
1
0
ULA
WHEN Σ3/4 = 0:
Σ1,1+.......+6,6=11
OR
WHEN Σ3/4 = 1:
Σ1,1+.......+6,6=15
COLUMN
1 2 3 4 5 6 7 8
ROW
1 2 3 4 5 6 7 8

FIG. 33

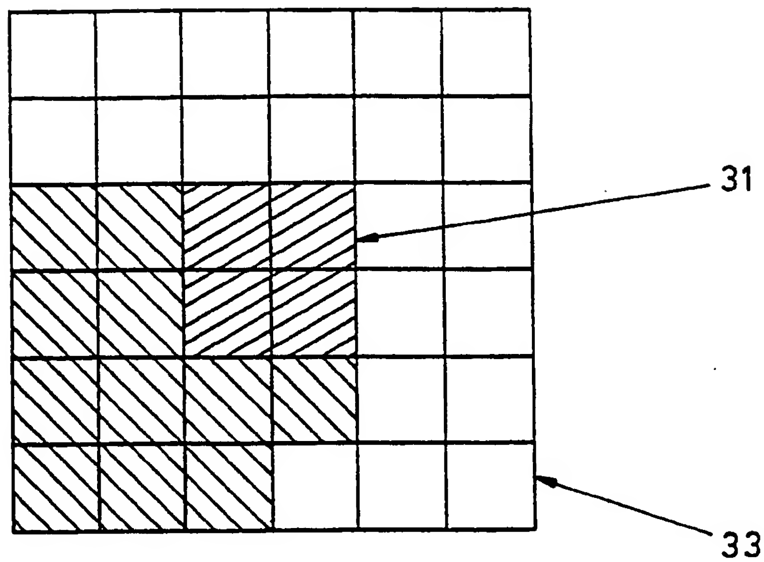

FIG. 34(a)

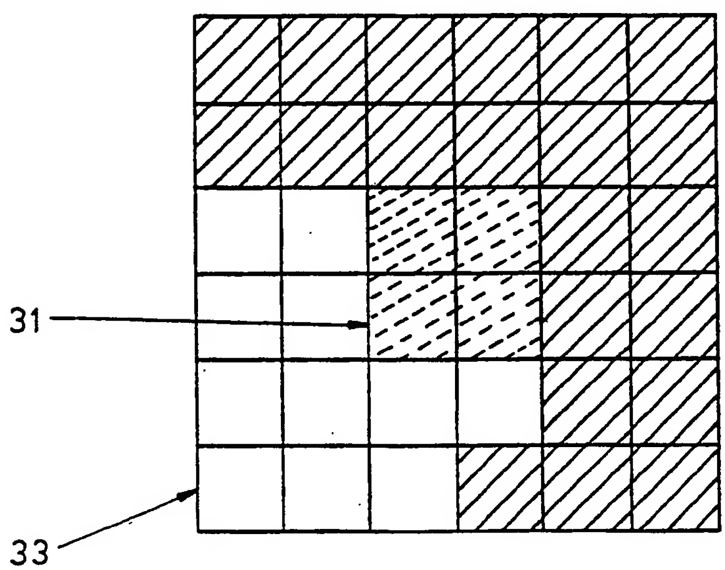

FIG. 34(b)

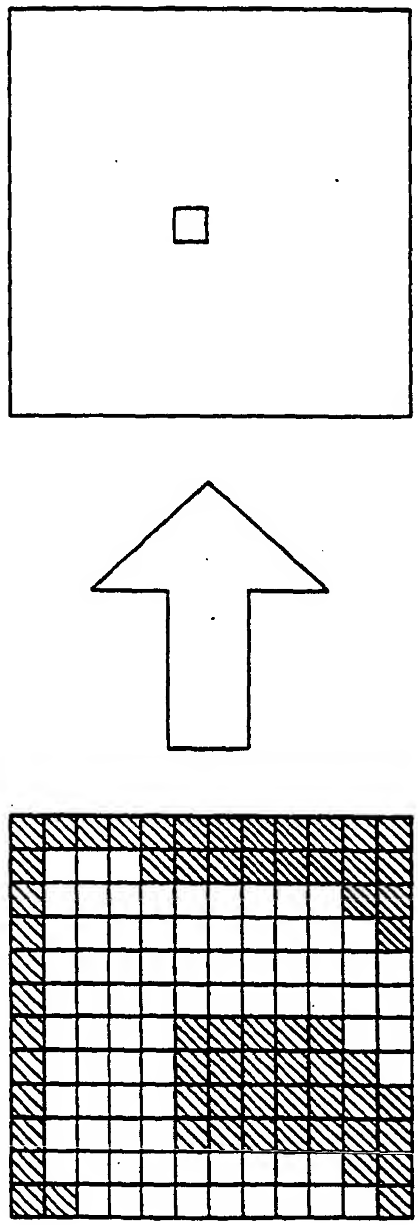

FIG. 35

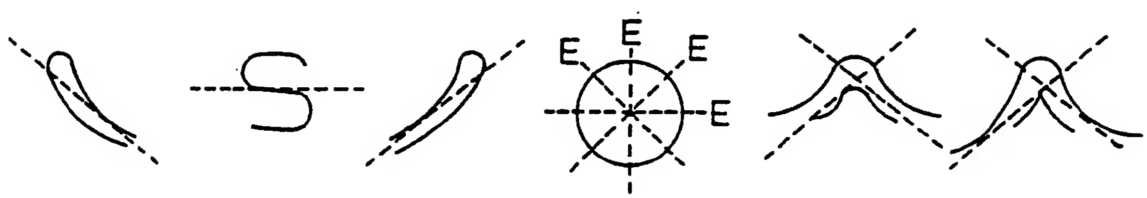

FIG. 36

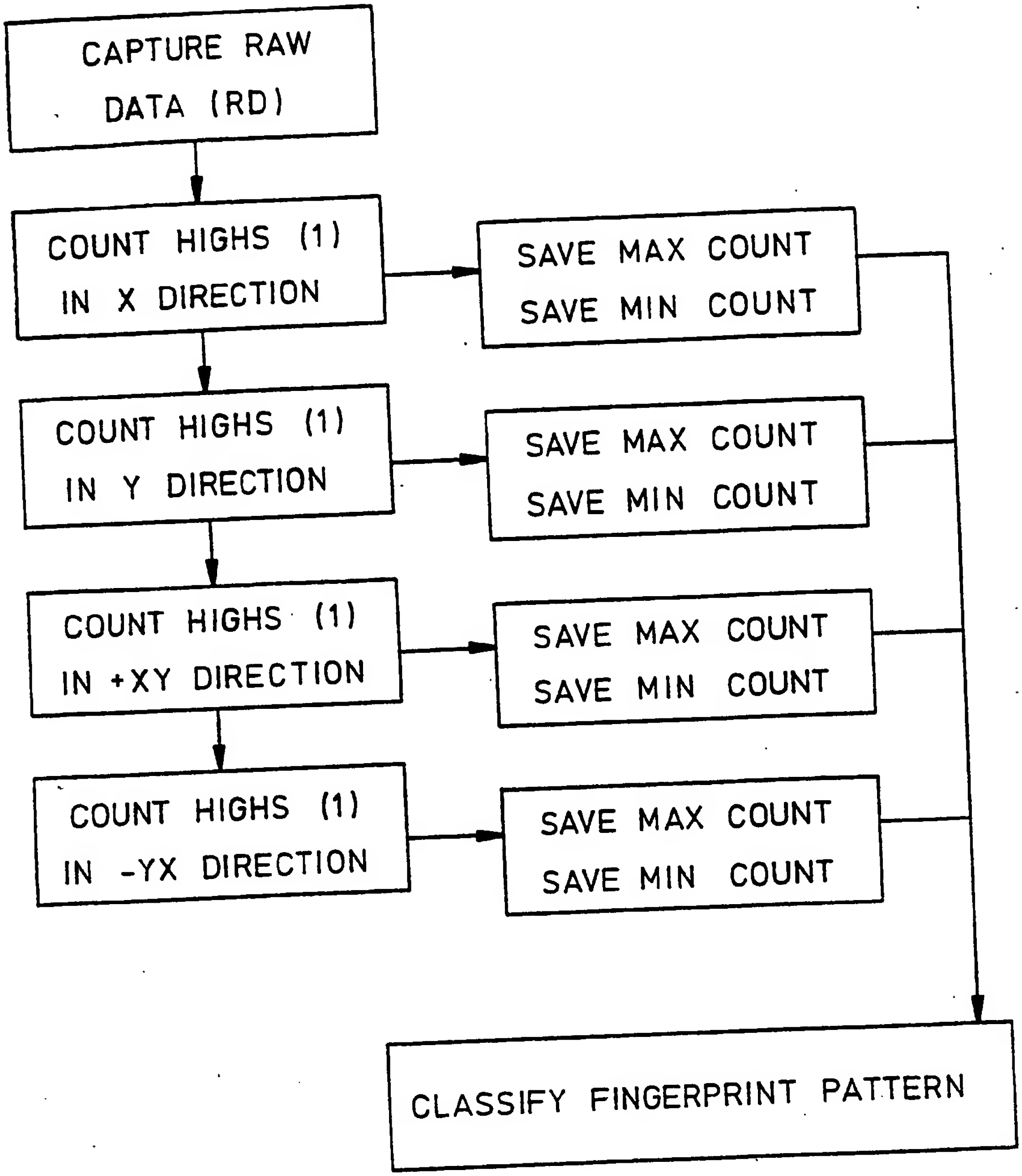
CAPTURE RAW DATA (RD)
COUNT HIGHS (1) IN X DIRECTION
SAVE MAX COUNT SAVE MIN COUNT
COUNT HIGHS (1) IN Y DIRECTION
SAVE MAX COUNT SAVE MIN COUNT
COUNT HIGHS (1) IN +XY DIRECTION
SAVE MAX COUNT SAVE MIN COUNT
COUNT HIGHS (1) IN -YX DIRECTION
SAVE MAX COUNT SAVE MIN COUNT
CLASSIFY FINGERPRINT PATTERN

FIG. 37

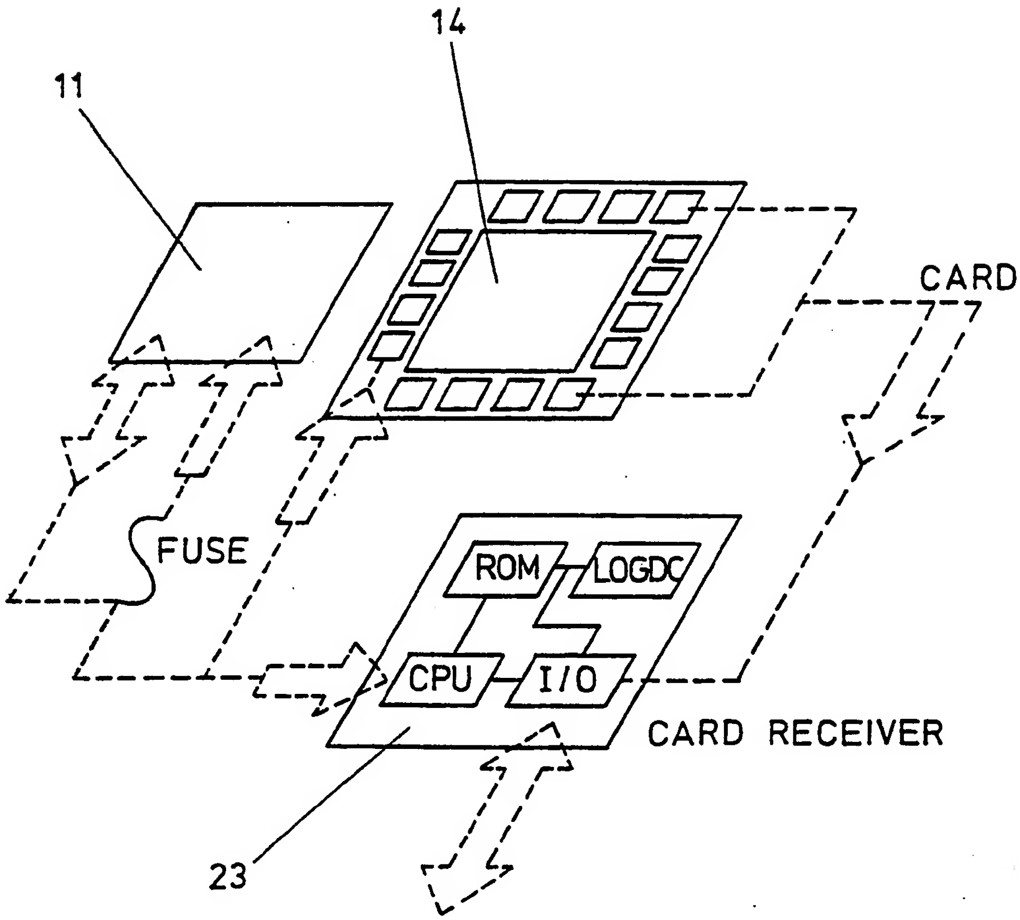

FIG. 38

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 94/00900

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 G07C9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 G07C G07F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,5 180 901 (HIRAMATSU) 19 January 1993 see column 4, line 10 - column 6, line 19; figures	1,2,14, 15
A		8,13,16, 22,42,50
X	US,A,4 577 345 (ABRAMOV) 18 March 1986 see column 4, line 17 - column 9, line 33; figures	1,2,14, 15
A		5,8,9, 13,19, 21,23,36

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
24 August 1994	27.09.94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Rakotondrajaona, C

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB,A,2 243 235 (ROSS) 23 October 1991 cited in the application see page 3, line 1 - page 6, line 22; figures	1-3,5, 8-15, 19-32, 36,40-42
A	EP,A,0 459 808 (GEC-MARCONI) 4 December 1991 cited in the application see page 4, column 4, line 15 - page 7, column 7, line 38; figures	1-3,7-9, 14-16,23
A	GB,A,2 217 497 (FINGERSCAN) 25 October 1989 see page 8, line 13 - page 9, line 28; figures	1,2,8, 15,22-25
A	WO,A,86 06527 (THE QUANTUM FUND) 6 November 1986 see page 12, line 23 - page 14, line 20; figures	1,2

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 94/00900

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-5180901	19-01-93	JP-A- 4024889	28-01-92
US-A-4577345	18-03-86	NONE	
GB-A-2243235	23-10-91	NONE	
EP-A-0459808	04-12-91	NONE	
GB-A-2217497	25-10-89	NONE	
WO-A-8606527	06-11-86	EP-A- 0218668	22-04-87
		GB-A,B 2174831	12-11-86
		JP-T- 62502575	01-10-87
		US-A- 4805223	14-02-89

Form PCT/ISA/210 (patent family annex) (July 1992)

Docket # P2001,0173

Applic. #______________________

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